

FLIGHT EFFECTS ON THE AERODYNAMIC AND ACOUSTIC CHARACTERISTICS
OF INVERTED PROFILE COANNULAR NOZZLES

COMPREHENSIVE DATA REPORT

CR-135189
(PWA-5509)

VOLUME 1

Prepared for
NASA Lewis Research Center
Under Contract NAS3-17866



March 1977

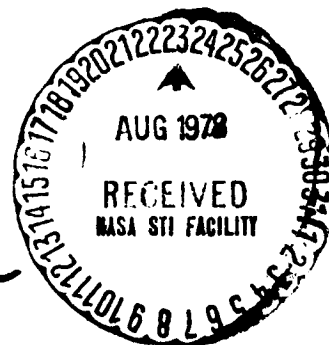
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PRATT & WHITNEY AIRCRAFT GROUP

Commercial Products Division



UNITED
TECHNOLOGIES

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OF INVERTED PROFILE COANNULAR NOZZLES,
VOLUME 1 Final Report (Pratt and Whitney
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FOREWORD

This report documents the work performed during the flight effects phase of Contract NAS3-17866. Due to the large amount of information generated under this program, the report has been prepared in three volumes.

Volume I contains a graphical presentation of data generated under this program.

Volume II contains the acoustic data from the acoustic tests of the convergent reference nozzle and the 0.75 area ratio coannular nozzle. This volume also contains the data processing routines used to scale the acoustic data and to correct the data for atmospheric attenuation.

Volume III contains the acoustic data from tests of the 0.75 area ratio coannular nozzle with ejector and the 1.2 area ratio coannular as well as the aerodynamic data acquired for the four test configurations.

The companion final report, NASA CR-3018, includes a description of the facilities used, the test hardware, the significant test results, the conclusions, and technology recommendations.

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INTRODUCTION

The acoustic and aerodynamic data measured during the flight effects phase of the program are presented in this volume in graphical form. The content of each section is described below.

Section A

This section presents comparisons of jet noise spectra at static conditions obtained from two facilities: United Technologies Research Center (UTRC) acoustic wind tunnel and the outdoor facility at the Government's Products Division, Pratt & Whitney Aircraft Group (formerly the Florida Research and Development Center, FRDC), used in a previous phase of this work. The comparisons include noise spectra measured at 90° and 150° relative to the upstream jet axis of the reference convergent nozzle, and the 0.75 and 1.2 area ratio coannular nozzles. In addition, the effects of screech tab suppression on noise spectra are also included. In these tests the tabs were installed around the nozzle lip in order to eliminate shock screech. In these tests the tabs were installed around the nozzle lip in order to eliminate shock screech arising from underexpanded supersonic nozzle operating conditions. A detailed discussion on the screech elimination is contained in the Final Report, NASA CR-3018.

Section B

The effect of relative velocity on OASPL directivity is presented in this section. Directivity plots are included for all configurations all operating conditions.

Section C

The effect of relative velocity on noise spectra is presented in this section. Third octave band Sound Pressure Level (SPL) plots are included for all configurations at typical operating conditions.

Section D

This section presents the Pressure Noise Level directivity at 2128 ft. sideline distance for the various tunnel velocities for all the coannular nozzle configurations at two operating conditions.

Section E

Nozzle exhaust plume velocity profiles are presented in this section for all operating conditions where traverse data was taken. The profiles of each configuration tested are compared at the four tunnel velocities.

Section F

This section presents measured nozzle thrust and flow coefficients (C_F and C_D) at various

tunnel velocities and nozzle pressure ratios for all the configurations tested. A curve of thrust coefficient adjustments which may be applied to the measured thrust coefficients is also presented to more completely define the performance potential of the nozzles. The adjustments identify the internal losses between the charging station and nozzle exit, and the overexpansion losses of the convergent divergent primary nozzles.

INDEX TO DATA CURVES

The data contained in this volume are presented by nozzle configurations which are identified by the numbers listed below.

Configuration
Number

Configuration Description

- | | |
|---|---|
| 1 | Convergent Reference Nozzle |
| 2 | 0.75 Area Ratio Coannular Nozzle |
| 3 | 0.75 Area Ratio Coannular Nozzle With Ejector |
| 4 | 1.2 Area Ratio Coannular Nozzle |

To facilitate locating data, an index for each section of this volume is presented, as follows:

SECTION A. STATIC NOISE DATA COMPARISONS – UTRC VS. FRDC

1. Without Screech Tabs

Nozzle Configurations	P_{tp}/P_{amb}	$T_{tp}(^{\circ}F)$	P_{tf}/P_{amb}	$T_{tf}(^{\circ}F)$	Page
1	1.3	250			A1, 2
1	1.53	250			A3, 4
1	1.8	250			A5, 6
1	2.5	250			A7, 8
1	1.3	800			A9, 10
1	1.8	800			A11, 12
1	2.5	800			A13, 14
1	3.2	800			A15, 16
2	1.53	250	1.3	800	A17, 18
2	1.53	250	1.8	800	A19, 20
2	1.53	250	2.5	800	A21, 22
2	1.53	250	3.2	800	A23, 24

2. With and Without Screech Tabs

1	1.3	250			A25, 26
1	1.53	250			A27, 28
1	1.8	250			A29, 30
1	2.5	250			A31, 32
1	1.3	800			A33, 34
1	1.8	800			A35, 36
1	2.5	800			A37, 38
1	3.2	800			A39, 40
2	1.53	200	1.3	800	A41, 42
2	1.53	200	2.5	800	A45, 46
2	1.53	200	3.2	800	A47, 48
4	1.53	250	1.3	800	A49, 50
4	1.53	250	1.8	800	A51, 52

SECTION B. EFFECT OF RELATIVE VELOCITY ON OASPL DIRECTIVITY

Nozzle Configuration	P_t/P_{amb}	$T_t(^{\circ}F)$	V_{∞} (fps)	Page
1	1.3	250	0, 100, 200, 340	B1
1	1.53	250	0, 100, 200, 340	B2
1	1.8	250	0, 100, 200, 340	B3
1	2.0	250	0, 100, 200, 340	B4
1	2.5	250	0, 100, 200, 340	B5
1	3.2	250	0, 100, 200, 340	B6
1	1.3	600	0, 100, 200, 340	B7
1	1.8	600	0, 100, 200, 340	B8

SECTION B. (Cont'd)

Nozzle Configuration	P_t/P_{amb}	$T_t(^{\circ}F)$	V_{∞} (fps)	Page
1	2.5	600	0, 100, 200, 340	B9
1	3.2	600	0, 100, 200, 340	B10
1	1.3	800	0, 100, 200, 340	B11
1	1.8	800	0, 100, 200, 340	B12
1	2.5	800	0, 100, 200, 340	B13
1	3.2	800	0, 100, 200, 340	B14

Nozzle Configuration	P_{tp}/P_{amb}	$T_{tp}(^{\circ}F)$	P_{tf}/P_{amb}	T_{tf}	V_{∞} (fps)	Page
2	1.53	250	1.3	250	0,100,200,340	B15
2	1.53	250	1.53	250	0,100,200,340	B16
2	1.53	250	1.8	250	0,100,200,340	B17
2	1.53	250	2.5	250	0,100,200,340	B18
2	1.53	250	3.2	250	0,100,200,340	B19
2	1.53	250	1.3	600	0,100,200,340	B20
2	1.53	250	1.8	600	0,100,200,340	B21
2	1.53	250	2.5	600	0,100,200,340	B22
2	1.53	250	3.2	600	0,100,200,340	B23
2	1.53	250	1.3	800	0,100,200,340	B24
2	1.53	250	1.8	800	0,100,200,340, 425	B24
2	1.53	250	2.5	800	0,100,200,340, 425	B26
2	1.53	250	3.2	800	0,100,200,340, 425	B27
2	Primary Off		1.3	800	0,200,340	B28
2	Primary Off		1.8	800	0,200,340	B29
2	Primary Off		2.5	800	0,200,340	B30
2	Primary Off		3.2	800	0,200,340	B31
3	1.53	250	1.3	250	0,100,200,340	B32
3	1.53	250	1.53	250	0,100,200,340	B33
3	1.53	250	1.8	250	0,100,200,340	B34
3	1.53	250	2.5	250	0,100,200,340	B35
3	1.53	250	3.2	250	0,100,200,340	B36
3	1.53	250	1.3	600	0,100,200,340	B37
3	1.53	250	1.8	600	0,100,200,340	B38
3	1.53	250	2.5	600	0,100,200,340	B39
3	1.53	250	3.2	600	0,100,200,340	B40
3	1.53	250	1.3	800	0,100,200,340	B41
3	1.53	250	1.8	800	0,100,200,340	B42
3	1.53	250	2.5	800	0,100,200,340, 425	B43
3	1.53	250	3.2	800	0,100,200,340, 425	B44

SECTION B. (Cont'd)

Nozzle Configuration	P_{tp}/P_{amb}	$T_{tp}(^{\circ}F)$	P_{tf}/P_{amb}	T_{tf}	V_{∞} (fps)	Page
4	1.53	250	1.3	250	0,100,200,340	B45
4	1.53	250	1.53	250	0,100,200,340	B46
4	1.53	250	1.8	250	0,100,200,340	B47
4	1.53	250	2.5	250	0,100,200,340	B48
4	1.53	250	3.2	250	0,100,200,340	B49
4	1.53	250	1.5	600	0,100,200,340	B50
4	1.53	250	1.8	600	0,100,200,340	B51
4	1.53	250	2.5	600	0,100,200,340	B52
4	1.53	250	3.2	600	0,100,200,340	B53
4	1.53	250	1.3	800	0,100,200,340	B54
4	1.53	250	1.8	800	0,100,200,340, 425	B55
4	1.53	250	2.5	800	0,100,200,340, 425	B56
4	1.53	250	3.2	800	0,100,200,340, 425	B57

SECTION C. EFFECT OF RELATIVE VELOCITY ON NOISE SPECTRA

Nozzle Configuration	P_{tp}/P_{amb}	$T_{tp}(^{\circ}F)$	P_{tf}/P_{amb}	$T_{tf}(^{\circ}F)$	Page
1	1.8	600			C1, 2
1	3.2	600			C3, 4
1	1.8	800			C5, 6
1	2.5	800			C7, 8
2	1.53	250	1.8	600	C9, 10
2	1.53	250	3.2	600	C11, 12
2	1.53	250	1.8	800	C13, 14
2	1.53	250	2.5	800	C15, 16
3	1.53	250	1.8	600	C17, 18
3	1.53	250	3.2	600	C19, 20
3	1.53	250	1.8	800	C21, 22
3	1.53	250	2.5	800	C23, 24
4	1.53	250	1.8	600	C25, 26
4	1.53	250	3.2	600	C27, 28
4	1.53	250	1.8	800	C29, 30
4	1.53	250	2.5	800	C31, 32

SECTION D. EFFECT OF RELATIVE VELOCITY ON PNL DIRECTIVITY

2	1.53	250	1.8	800	D1
2	1.53	250	2.5	800	D2
3	1.53	250	1.8	800	D3

SECTION D. (Cont'd)

Nozzle Configuration	P_{tp}/P_{amb}	$T_{tp}(^{\circ}F)$	P_{tf}/P_{amb}	$T_{tf}(^{\circ}F)$	Page
3	1.53	250	2.5	800	D4
4	1.53	250	1.8	800	D5
4	1.53	250	2.5	800	D6

SECTION E. NOZZLE EXHAUST PLUME VELOCITY PROFILES

1	2.5	800			E1
2	1.53	250	2.5	800	E2
2	Primary Off		2.5	800	E3
3	1.53	250	1.3	800	E4
3	1.53	250	1.8	800	E5
3	1.53	250	2.5	800	E6
3	1.53	250	3.2	800	E7
4	1.53	250	2.5	800	E8

SECTION F. EFFECT OF RELATIVE VELOCITY ON AERODYNAMIC PERFORMANCE

Nozzle Configuration	P_t/P_{amb}	P_{tf}/P_{amb}	V_{∞} (fps)	Page
1	1.3 - 3.2		0,200,340,425	F1
2	1.53	1.3 - 3.2	1,200,340,425	F2
3	1.53	1.3 - 3.2	0,200,340,425	F3
4	1.53	1.3 - 3.2	0,200,340,425	F4
2	Primary Off	1.3 - 3.2	0	F5
2	1.3 - 3.2	Fan Off	0	F6
Thrust Adjustments				F7

Symbols

P = pressure
T = temperature
V = velocity

Subscripts

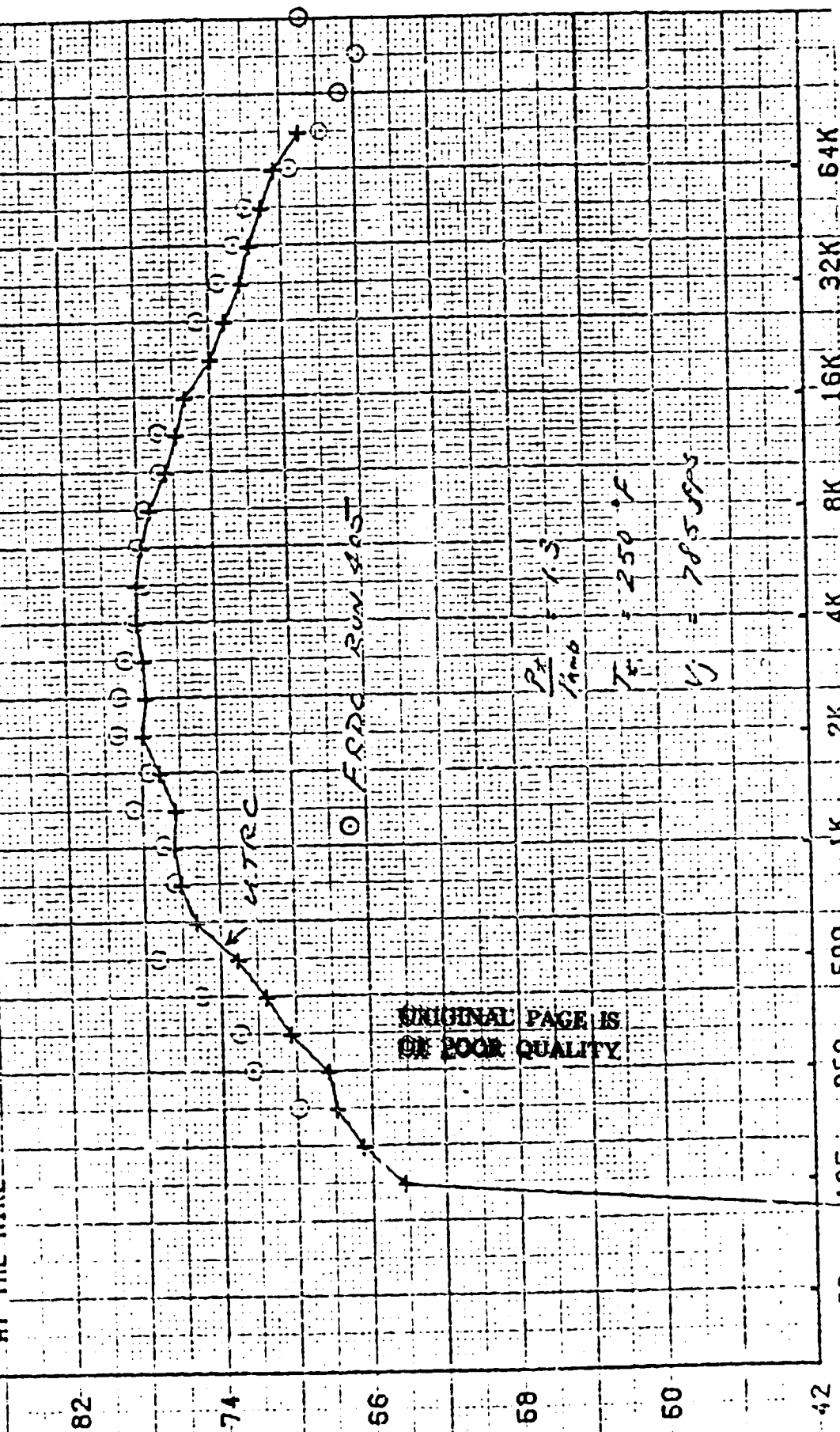
amb = ambient
f = fan
p = primary
t = total
 ∞ = tunnel stream

DATA CURVES

20031F DBIF ACOUSTIC TUNNEL JET NOISE TEST CONY NOZ CONF 1 TAPE 4219 IC-2049

MICROPHONE ANGLE = 90 DEG
ENGINE CONDITION = 1831
AT THE MIKE

10 ft radius
THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



ORIGINAL PAGE IS
OF POOR QUALITY

$\frac{P_{th}}{P_{amb}} = 1.3$
 $f_c = 250 \text{ Hz}$
 $V = 785 \text{ ft}^3$

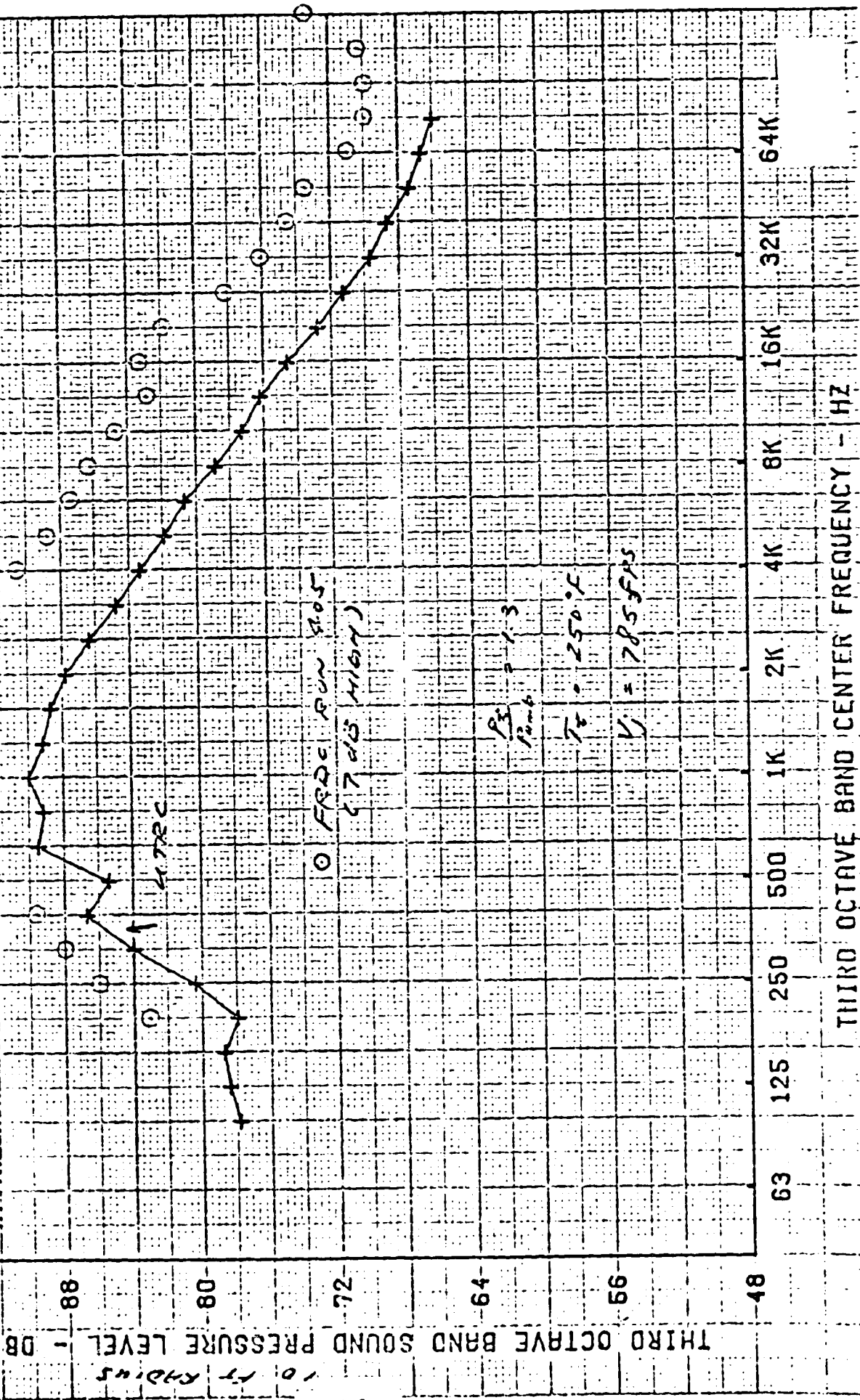
THIRD OCTAVE BAND CENTER FREQUENCY - HZ

20031E DBIF ACOUSTIC JUNNEL JET NOISE TEST CONV NOZ CONF 1 TRPE 4219 0.2049

MICROPHONE ANGLE = 160 DEG

ENGINE CONDITION = 1831

AT THE MIKE



20031F DB1F ACOUSTIC TUNNEL JET NOISE TEST CONV NOZ CONF 1 TAPE 4219 10.2049

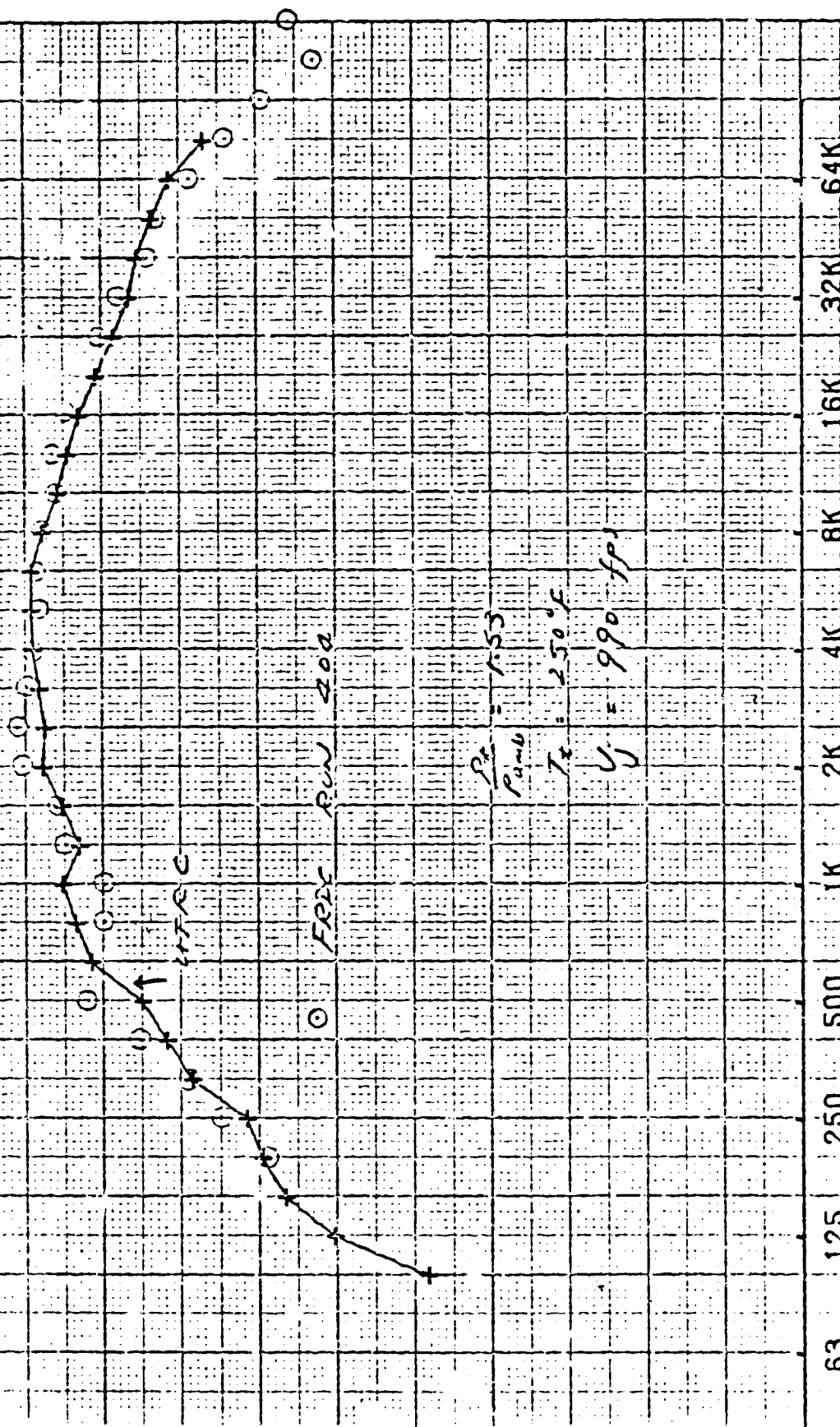
MICROPHONE ANGLE = 90 DEG

ENGINE CONDITION = 1834

AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

94 86 78 70 62 54 46



THIRD OCTAVE BAND CENTER FREQUENCY - HZ

63 125 250 500 1K 2K 4K 8K 16K 32K 64K

20031F DB1F ACOUSTIC TUNNEL JET-NOISE TEST CONV-NO2 CONF 1 TAPE 4219 10-2049

MICROPHONE ANGLE = 160 DEO

ENGINE CONDITION = 1034

AT THE HIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

10 FT RADII

WTRC

FEDE RUN 404

$\frac{P_c}{P_{amb}} = 1.53$

$T_c = 250^\circ F$

$V_c = 990 \text{ fps}$

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THIRD OCTAVE BAND CENTER FREQUENCY - HZ

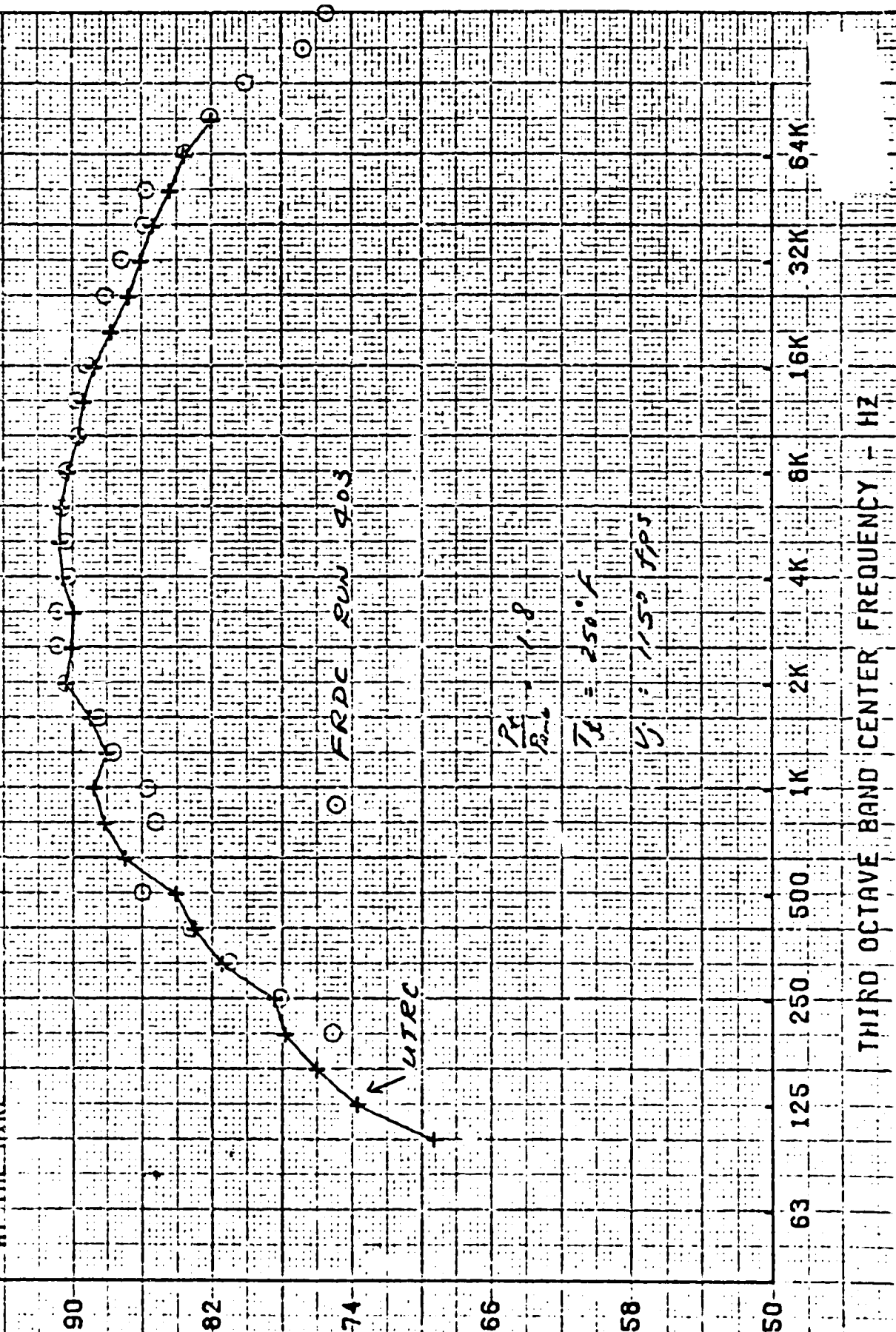
63 125 250 500 1K 2K 4K 8K 16K 32K 64K

20031F DBTE ACOUSTIC TUNNEL JET NOISE TEST CONV NO2 CONF 1 TAPE 4218 10.2049

98 MICROPHONE ANGLE = 90 DEG
 ENGINE CONDITION = 1837
 AT THE HIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL DB

10 FT RADII

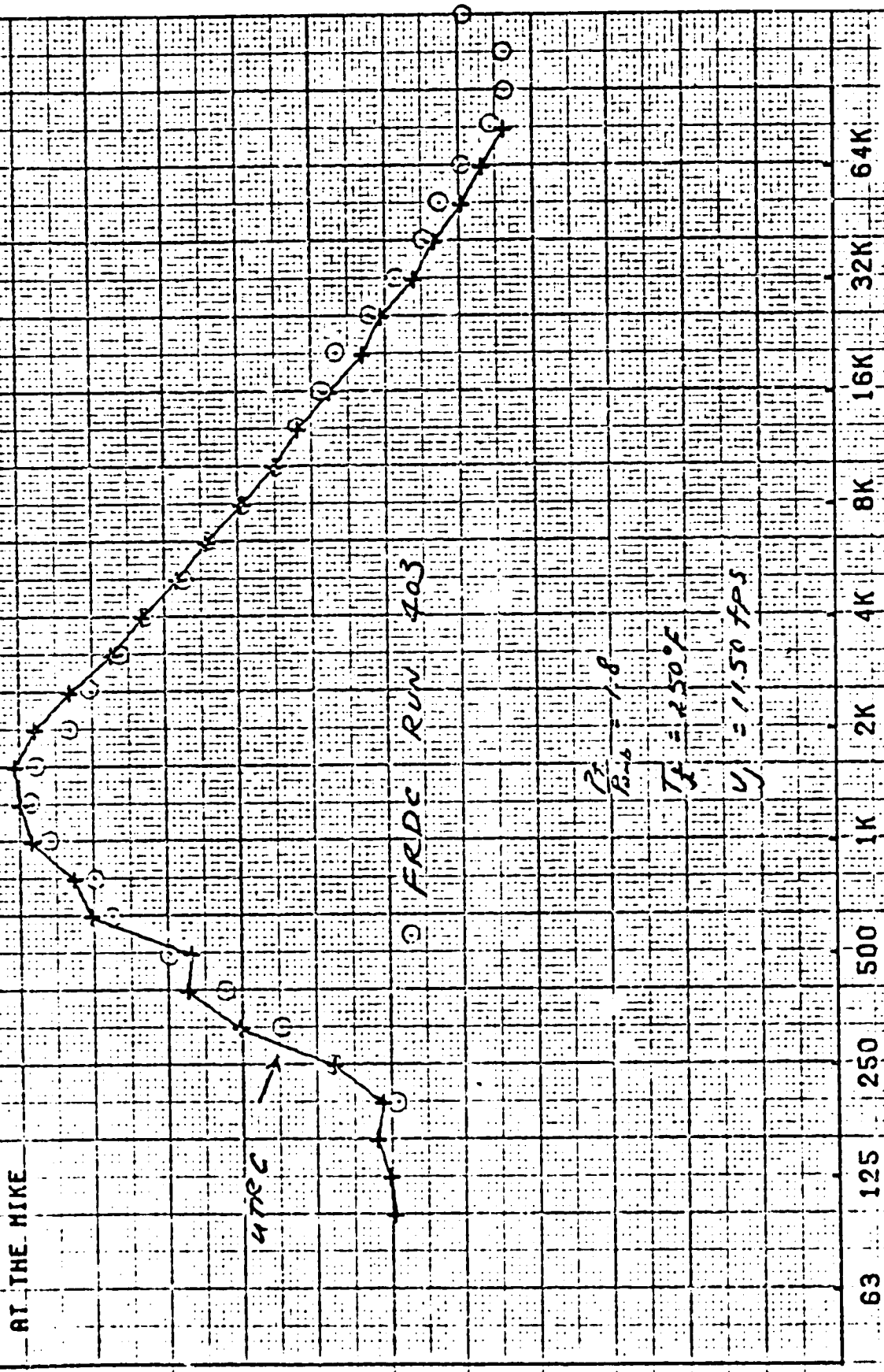


20031F DBIF ACOUSTIC TUNNEL JET NOISE TEST CONV NOZ CONF 1 TAPE 4219 10-2049

MICROPHONE ANGLE = 160 DEG
ENGINE CONDITION = 1837
AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

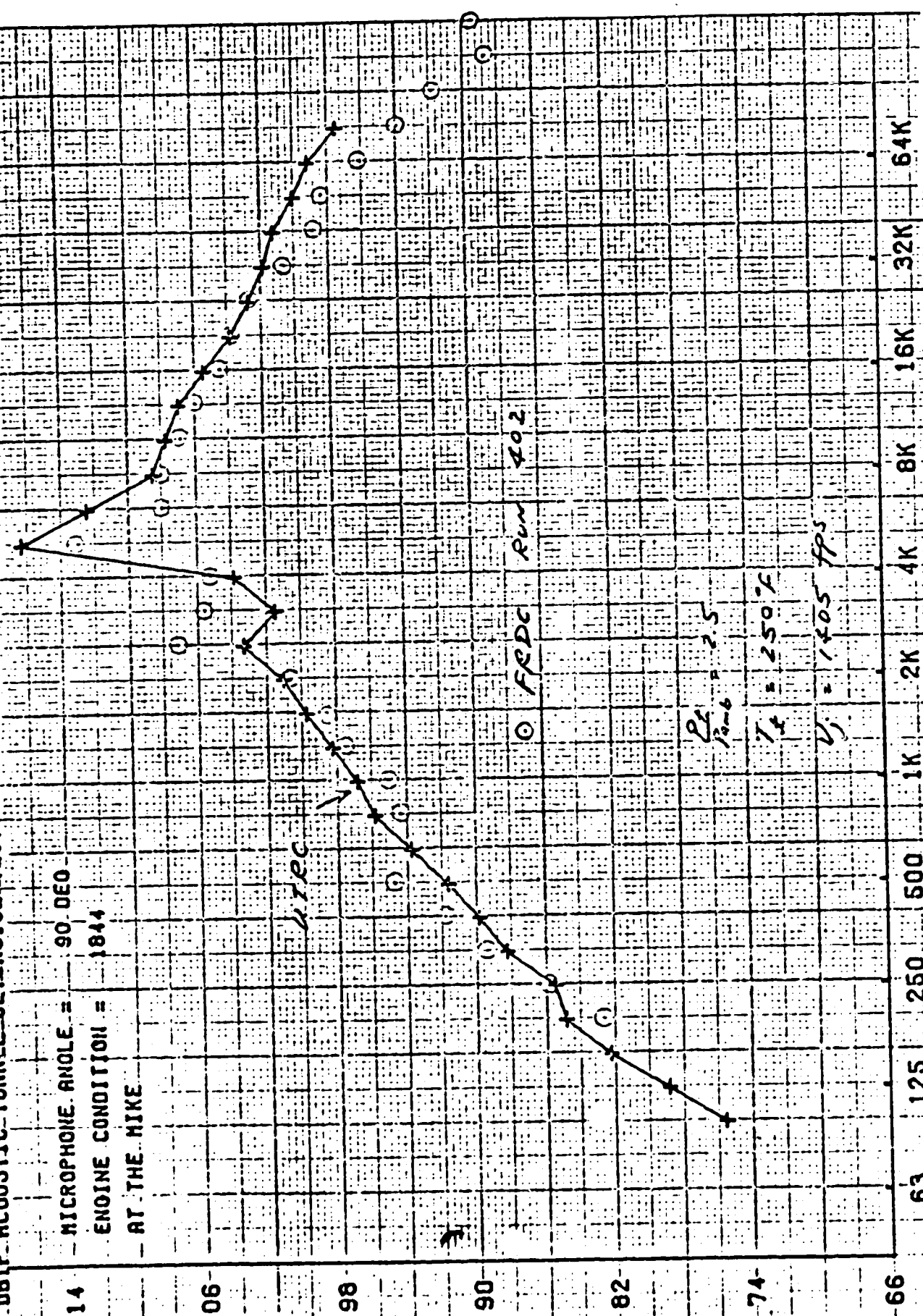


20031F DB1F ACOUSTIC TUNNEL JET NOISE TEST CONV NO3 CONF 1 TAPE 4219 10.2049

MICROPHONE ANGLE = 90 DEO
 ENGINE CONDITION = 1844
 AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

10 FT RADIUS



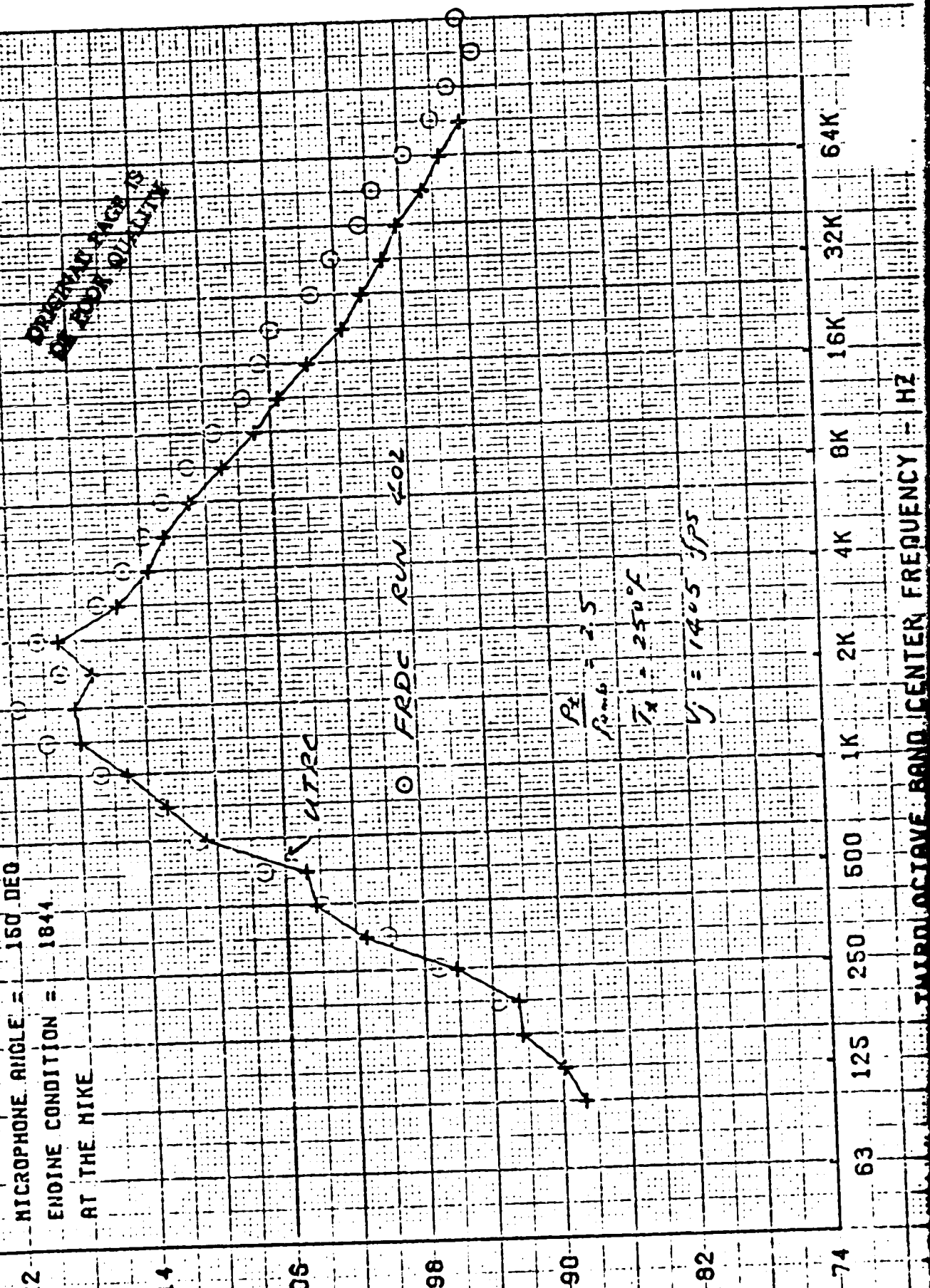
THIRD OCTAVE BAND CENTER FREQUENCY - HZ

20031F DB1F ACOUSTIC TUNNEL JET NOISE TEST CONV NO2 CONF 1 TAPE 4219 10.2049

MICROPHONE ANGLE = 150 DEG
 ENGINE CONDITION = 1844
 AT THE HIKE

PRESSURE RISE IS
 OF GOOD QUALITY

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



$\frac{P_2}{P_{ref}} = 2.5$
 $T_2 = 250^\circ F$
 $V = 1405 \text{ f/s}$

20031F DBIF ACOUSTIC TUNNEL JET NOISE TEST CONV NO2 CONF 1 TAPE 4220 10-2049

MICROPHONE ANGLE = 90 DEG

ENGINE CONDITION = 1882

AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

UTRC

FEDC RVN 2501

ORIGINAL FILED
OF FOUR QUALITY

$$\frac{P_t}{P_{amb}} = 1.3$$

$$T_t = 800^\circ F$$

$$U_j = 1050 \text{ fps}$$

63

125

250

500

1K

2K

4K

8K

16K

32K

64K

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

20031F DB1F ACOUSTIC TUNNEL JET NOISE TEST CONY NO2 CONF 1 TAPE 4220 10.2049

MICROPHONE ANGLE = 150 DEG

ENGINE CONDITION = 1882

AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

10 ft radius

UTRC

FRDC RUN 2501

$\frac{P_2}{P_{amb}} = 1.3$

$T_2 = 800^\circ F$

$V_2 = 1050 \text{ f/s}$

ORIGINAL PAGE
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THIRD OCTAVE BAND CENTER FREQUENCY - HZ

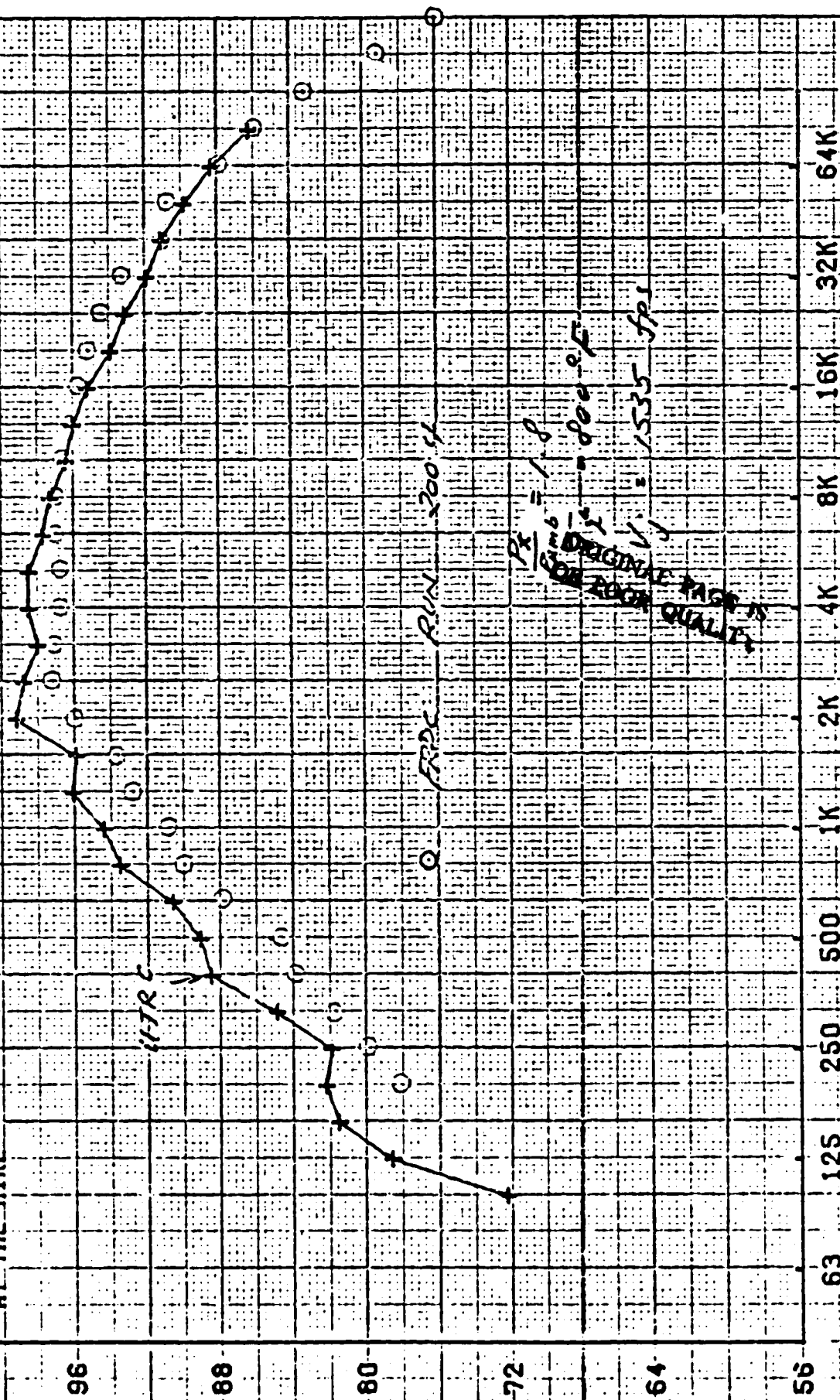
20031F DBIF ACOUSTIC TUNNEL JET NOISE TEST CONV NO2 CONF 1 TAPE 4220 10.2048

MICROPHONE ANGLE = 90 DEO

ENGINE CONDITION = 1879

AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



FRDC RUN 200 4

$\frac{P}{P_0} = 1.8$
 $\frac{P}{P_0} = 800 \text{ c.f.}$
 $\frac{P}{P_0} = 1535 \text{ fps}$

QUALITY

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

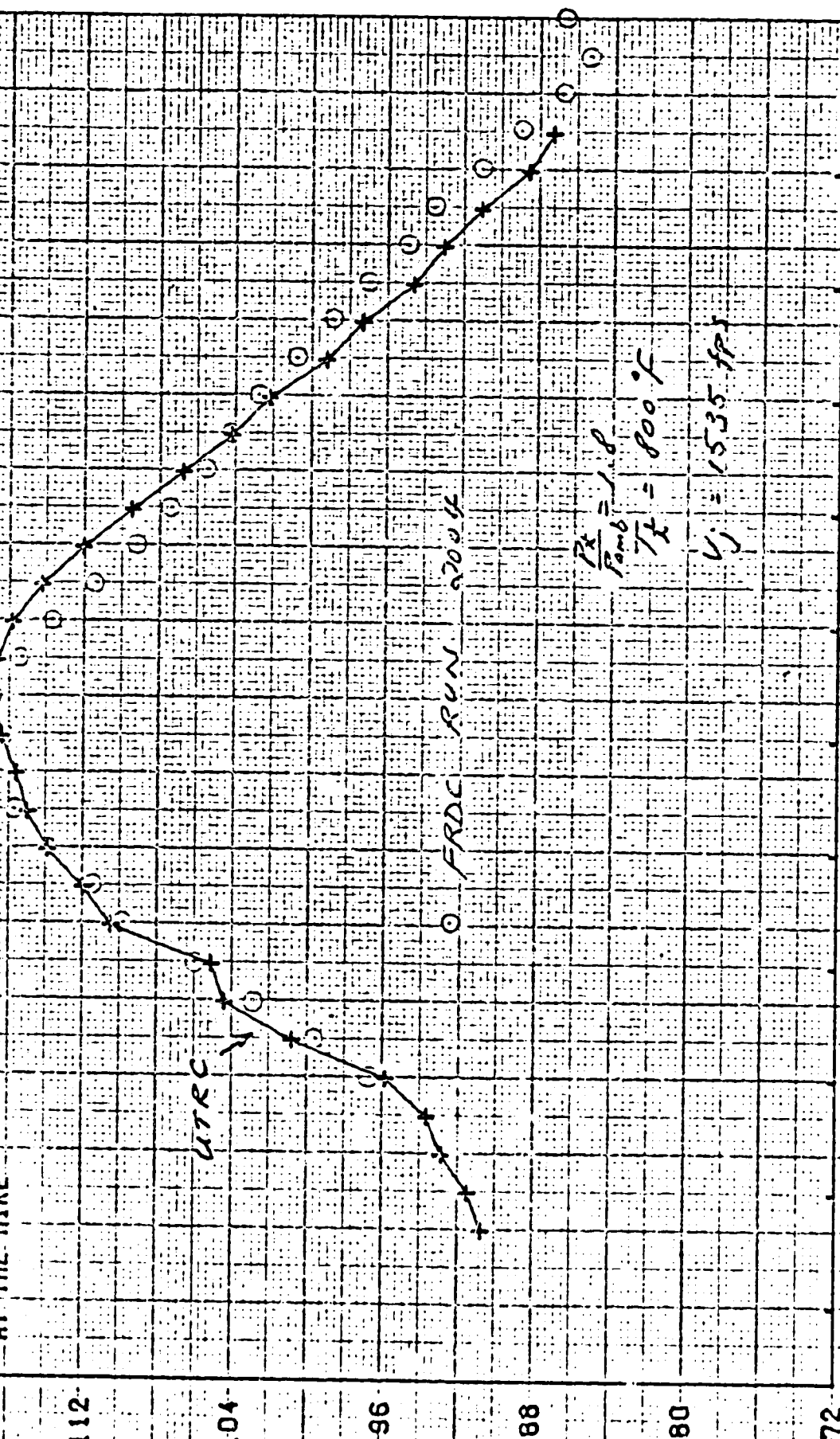
20031F DB1F ACOUSTIC TUNNEL JET NOISE TEST CONV N02 CONF 1 TAPE 4220 10-2049

MICROPHONE ANGLE = 160 DEG

ENGINE CONDITION = 1879

AT THE MIKE

10 FT RADIUS
THIRD OCTAVE BAND SOUND PRESSURE LEVEL DB



THIRD OCTAVE BAND CENTER FREQUENCY - HZ

20031F DB1F ACOUSTIC TUNNEL JET NOISE TEST CONY NO2 CONF 1 TAPE 4220 10.2048

MICROPHONE ANGLE = 90 DEG

ENGINE CONDITION = 1665

AT THE HIKE

10 FT RADII

THIRD OCTAVE BAND SOUND PRESSURE LEVEL DB

112

104

96

88

80

72

64

63

125

250

500

1K

2K

4K

8K

16K

32K

64K

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

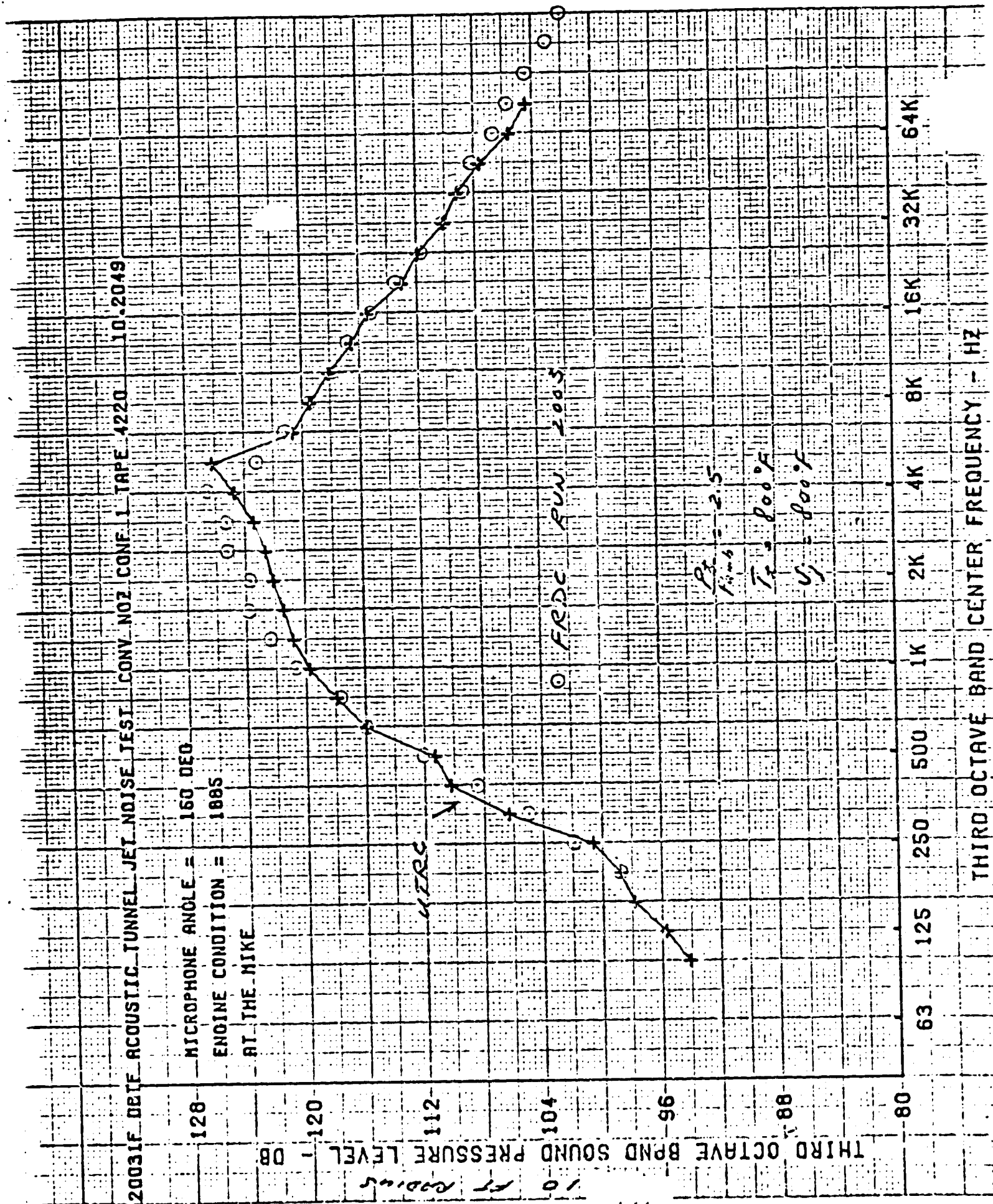
UTRC

FRDC RUN 2003

$\frac{P_t}{P_{amb}} = 2.5$

$T_r = 800^\circ F$

$V_j = 1825 \text{ fps}$



20031E DBTF ACOUSTIC TUNNEL JET NOISE TEST CONV NOZ CONF TAPE 4220 10.2049

MICROPHONE ANGLE = 90 DEG
ENGINE CONDITION = 1600
AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

10 FT RADII

117EC

FRDC

RUN 3002

ORIGINAL
OF FOUR
PAGE 2

$$\frac{P_c}{P_{amb}} = 3.2$$

$$T_c = 800^\circ F$$

$$U_c = 2080 \text{ FPS}$$

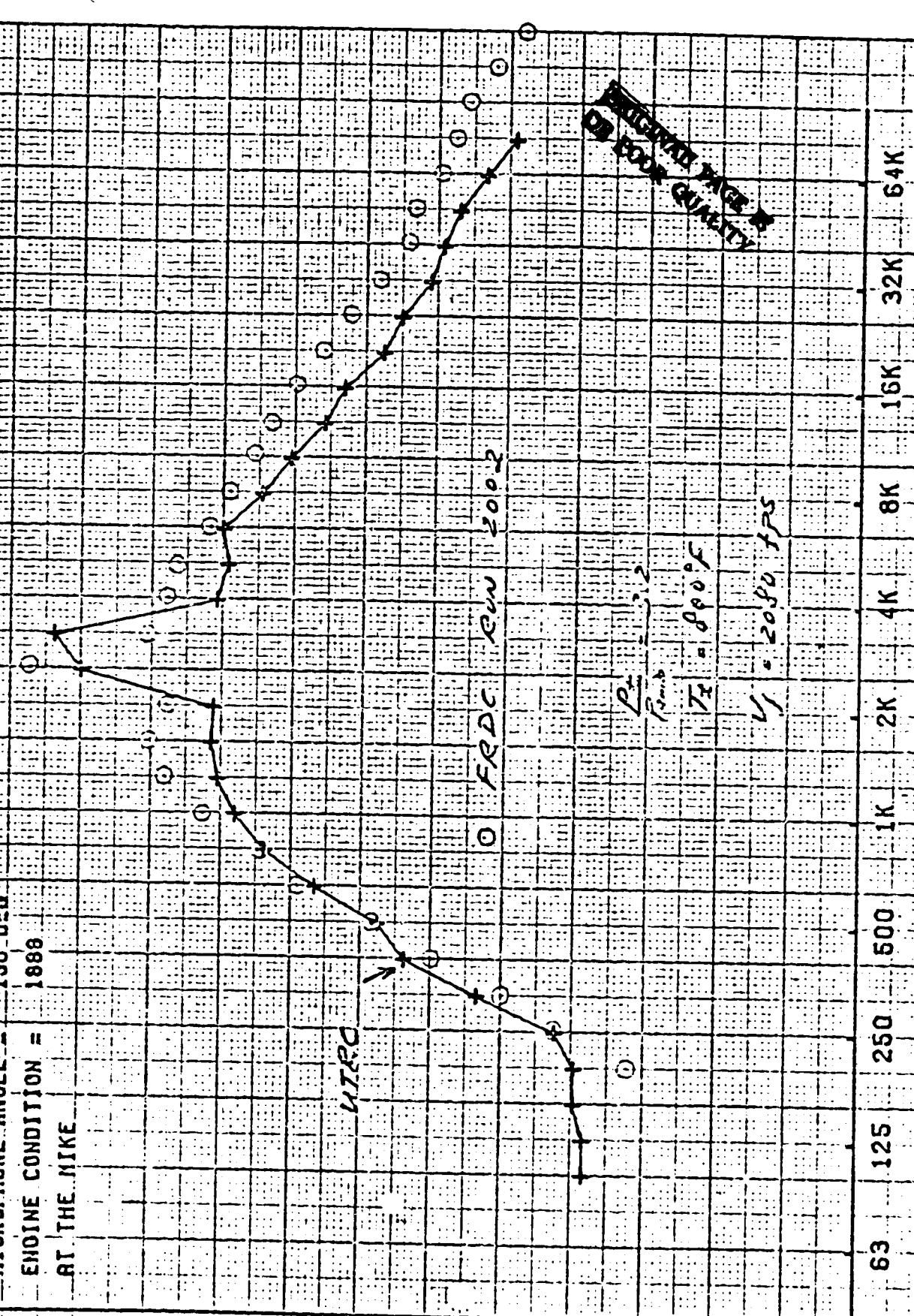
THIRD OCTAVE BAND CENTER FREQUENCY - HZ

63 125 250 500 1K 2K 4K 8K 16K 32K 64K

20031F DBIE ACOUSTIC TUNNEL JET NOISE TEST CONY NO2 CONF 1 TAPE 4220 10.2049

MICROPHONE ANGLE = 150 DEG
 ENGINE CONDITION = 1888
 AT THE MIKE

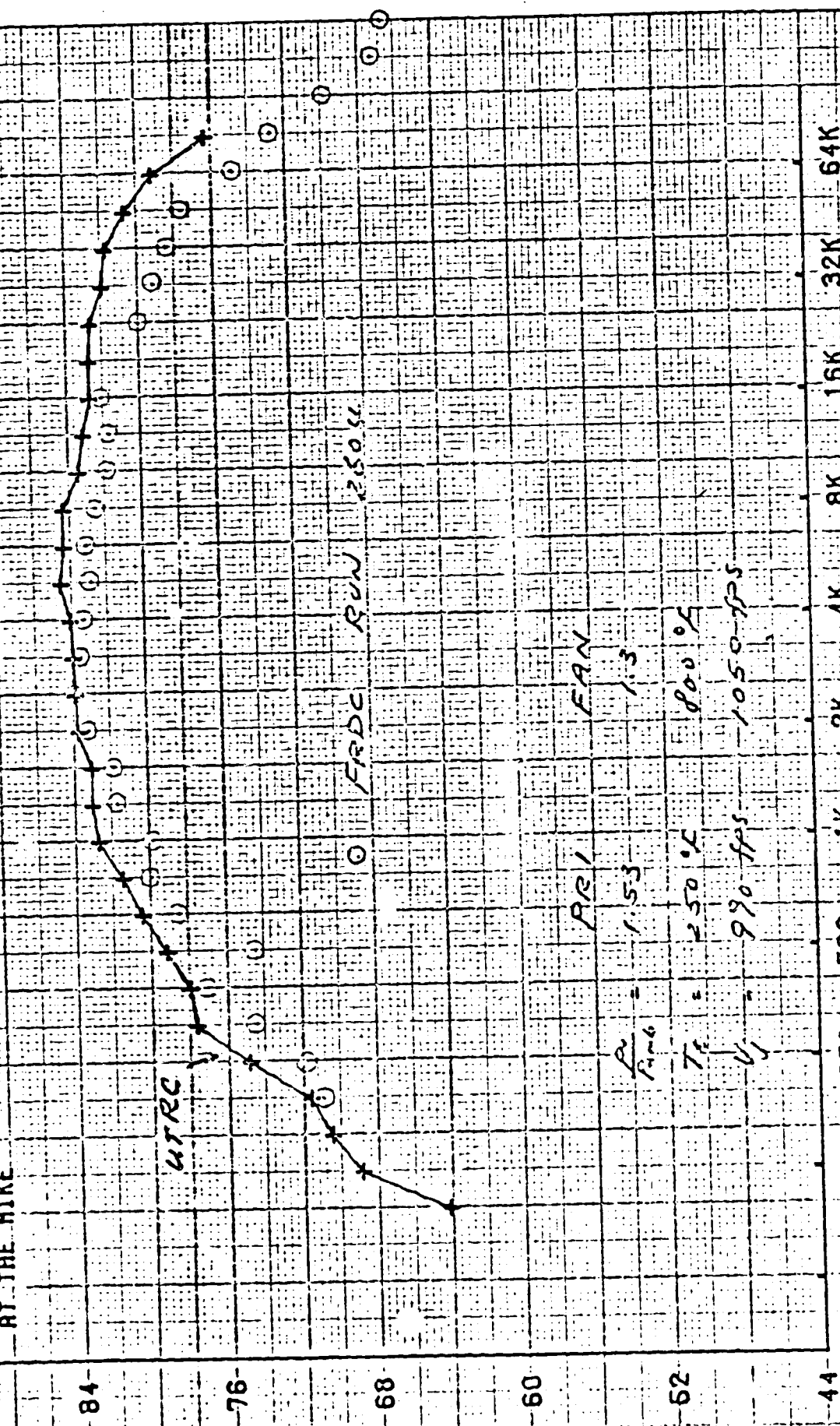
10 FT RADIUS
 THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



2003F DBTE JET NOISE TEST COANNULAR NOZ AR=0.75 CONF 2 TAPE 4222 10-2049

MICROPHONE ANGLE = 90 DEG
 ENGINE CONDITION = 3303
 AT THE HIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



PR1 FAN

$\frac{P}{P_{ref}} = 1.53$

$T_e = 250^\circ F$

$V_j = 990 \text{ fps}$

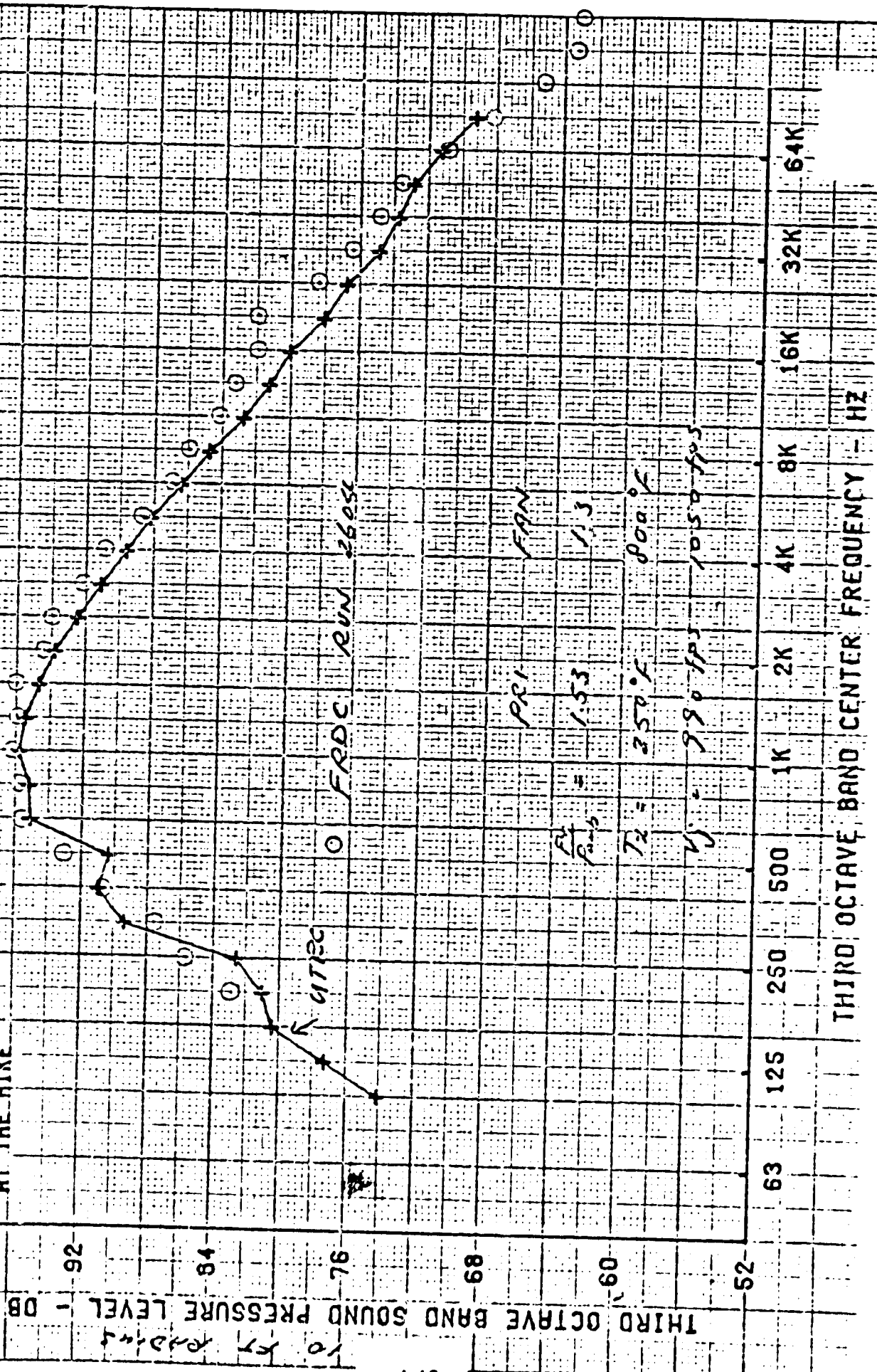
800%

1050-825

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

20033F DBTF JET NOISE TEST CORNULAR NOZ AR=0.75 CONF 2 TAPE 4222 10.2049

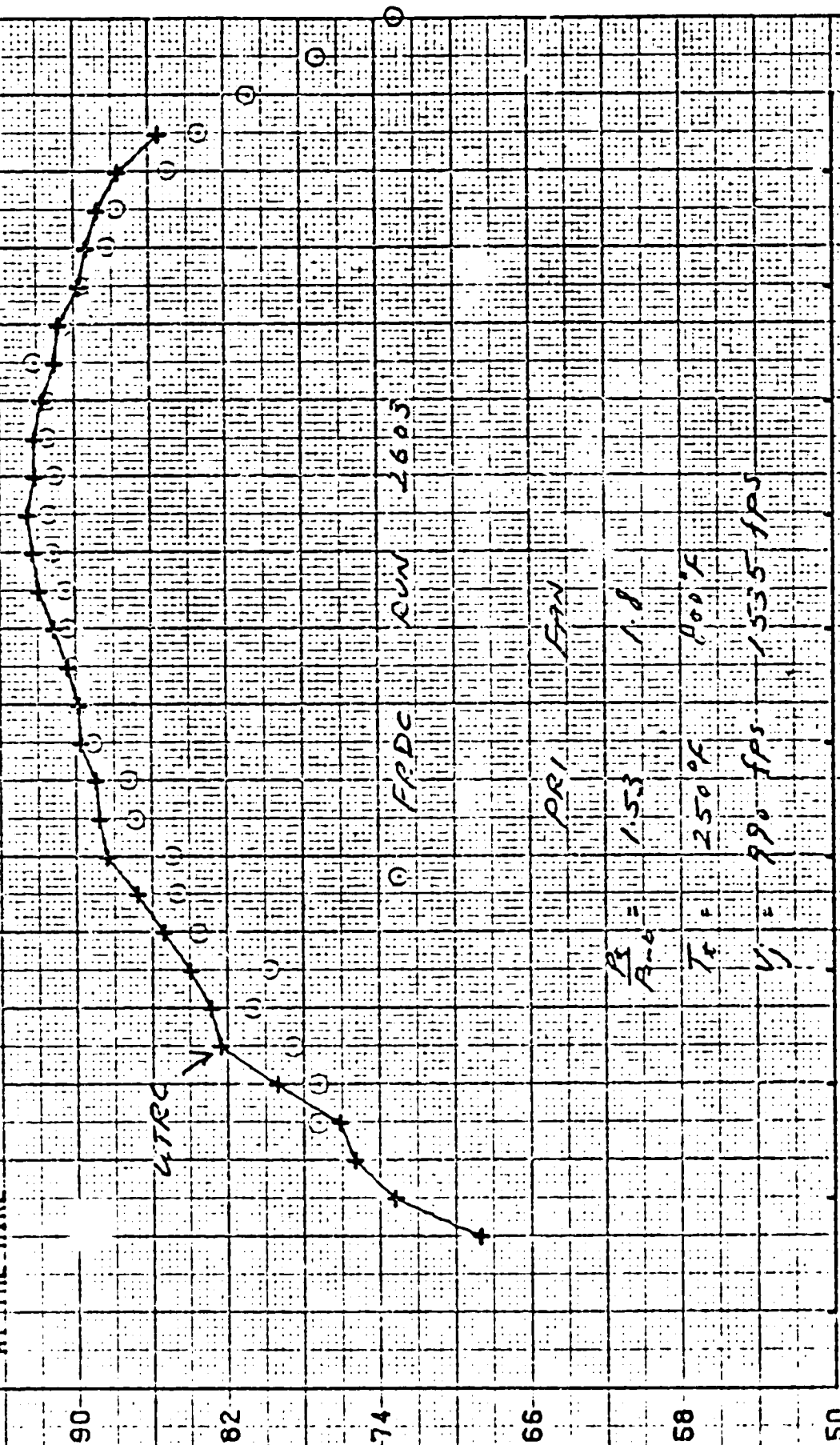
MICROPHONE ANGLE = 160 DEG
ENGINE CONDITION = 3303
AT THE MIKE



20033E DB(F) JET NOISE TEST COANNULAR NO2 AR=0.76 CONF 2 TAPE 4222 10-2049

MICROPHONE ANGLE = 90 DEG
ENGINE CONDITION = 3304
AT THE HIKE

10 FT RADIUS
THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



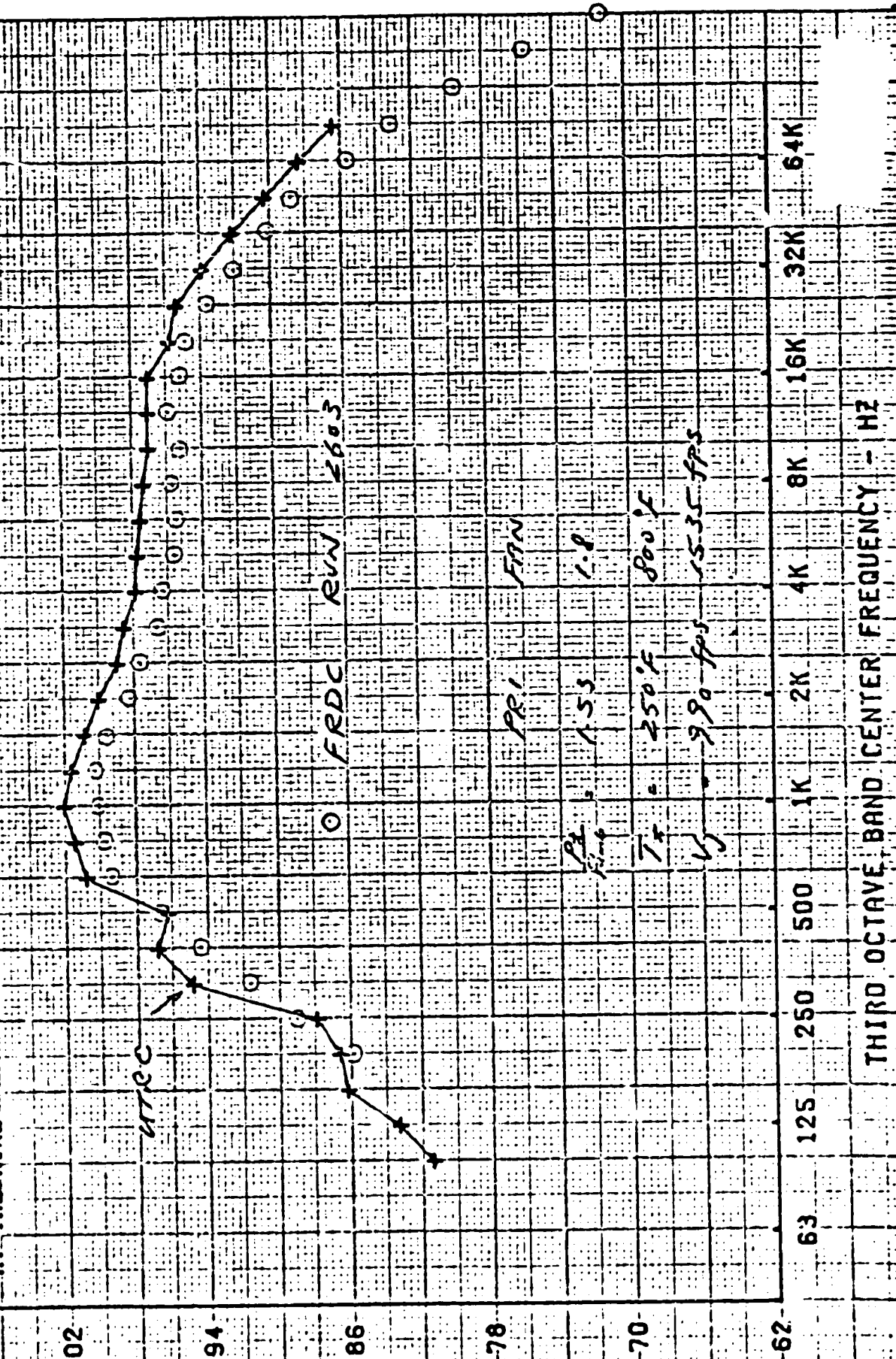
THIRD OCTAVE BAND CENTER FREQUENCY - HZ

63	125	250	500	1K	2K	4K	8K	16K	32K	64K
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20033F DB1F JET NOISE TEST COANNULAR NOZ AR=0.75 CONF 2 TAPE 4222 10.2049

MICROPHONE ANGLE = 150 DEG
 ENGINE CONDITION = 3304
 AT THE HIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



PR1

FRDC

RW

1.8

1.53

800°F

250°F

1535 f/s

990 f/s

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

20033F DBE JET NOISE TEST CONTINUED NO2 PR=0.75 CONF 2 TAPE 4222 10.2049

MICROPHONE ANGLE = 90 DEG
ENGINE CONDITION = 3302
AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

10 ft Radius

WTEC
FREQ RUN 2302

FAN

PR1

2.5

1.53

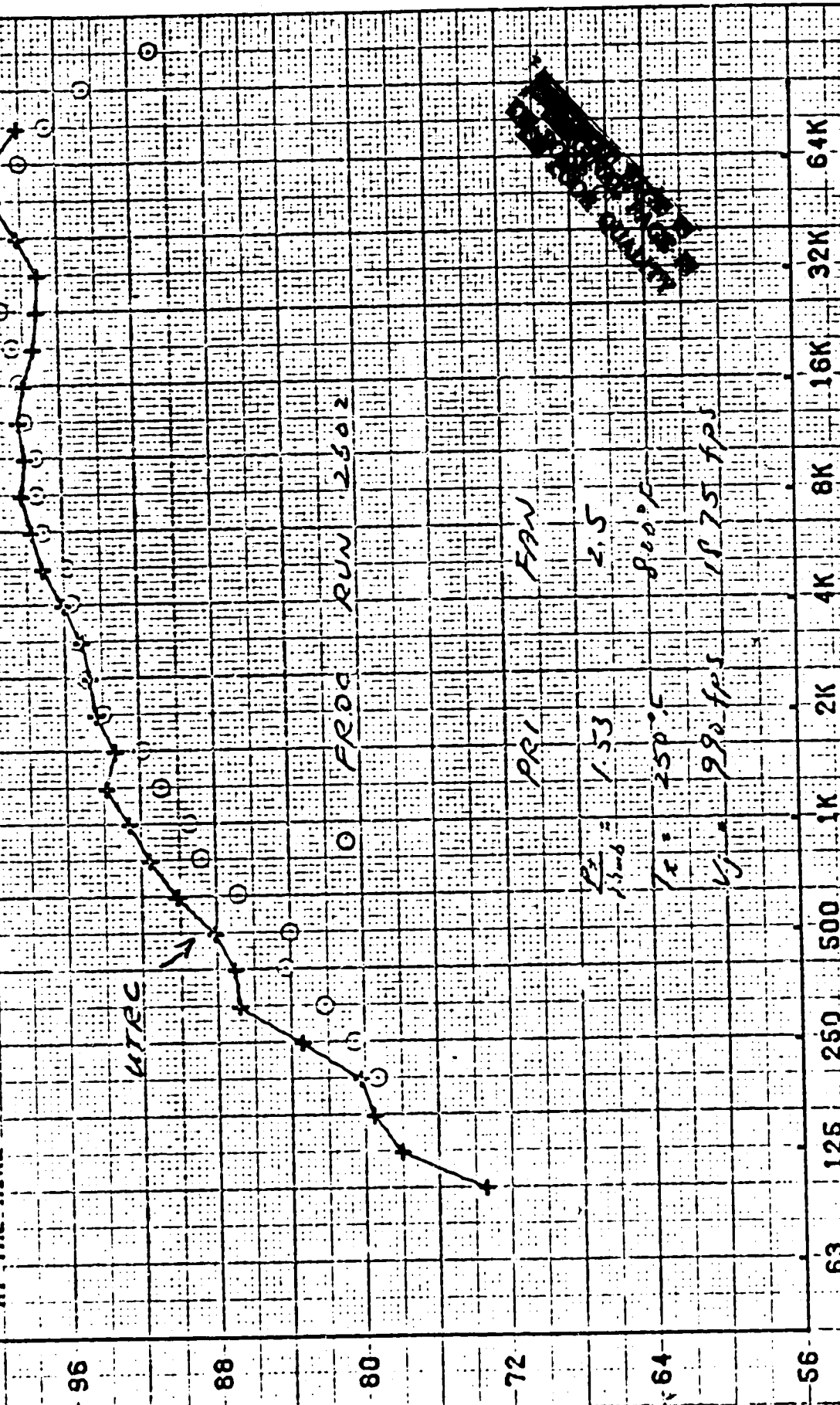
800°F

250°F

1875 FPS

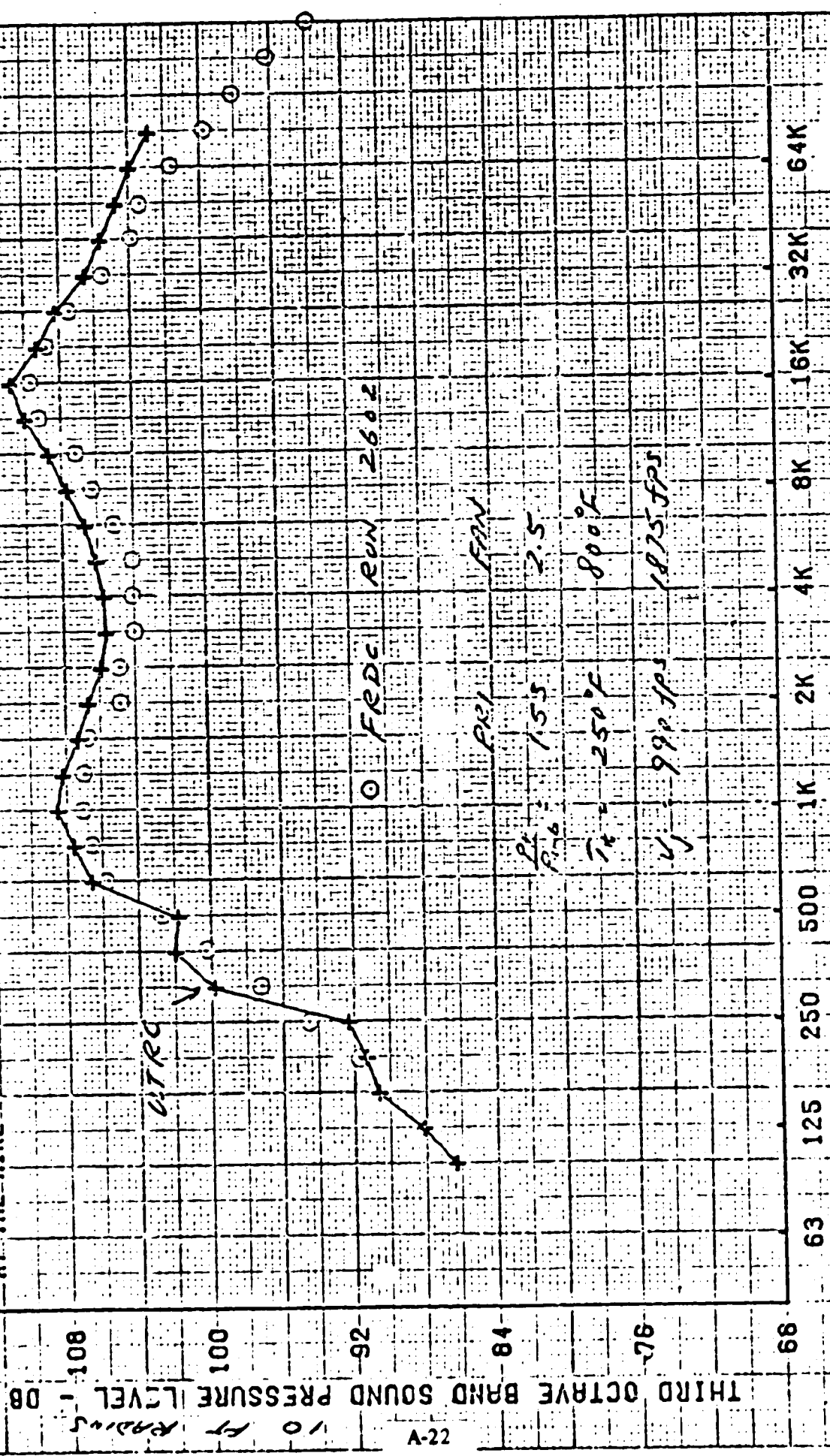
990 FPS

THIRD OCTAVE BAND CENTER FREQUENCY - HZ



20033F DBTF JET NOISE TEST COANNULAR NOZ AR=0.75 CONF 2 TAPE 4222 10.2049

MICROPHONE ANGLE = 150 DEG
ENGINE CONDITION = 9302
AT THE MIKE



20033F DBIF JET NOISE TEST CORNULAR NOZ AR=0.75 CONF 2 TARE 4222 10.2049

MICROPHONE ANGLE = 90 DEG

ENGINE CONDITION = 3301

AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

10 ft radius

UTEC

FRDC RUN 2601

FAN

PEI

$P_{FAH} = 1.53$

3.2

$T_a = 250^\circ F$

800°F

$V_j = 230 \text{ fpi}$

2080 f/s

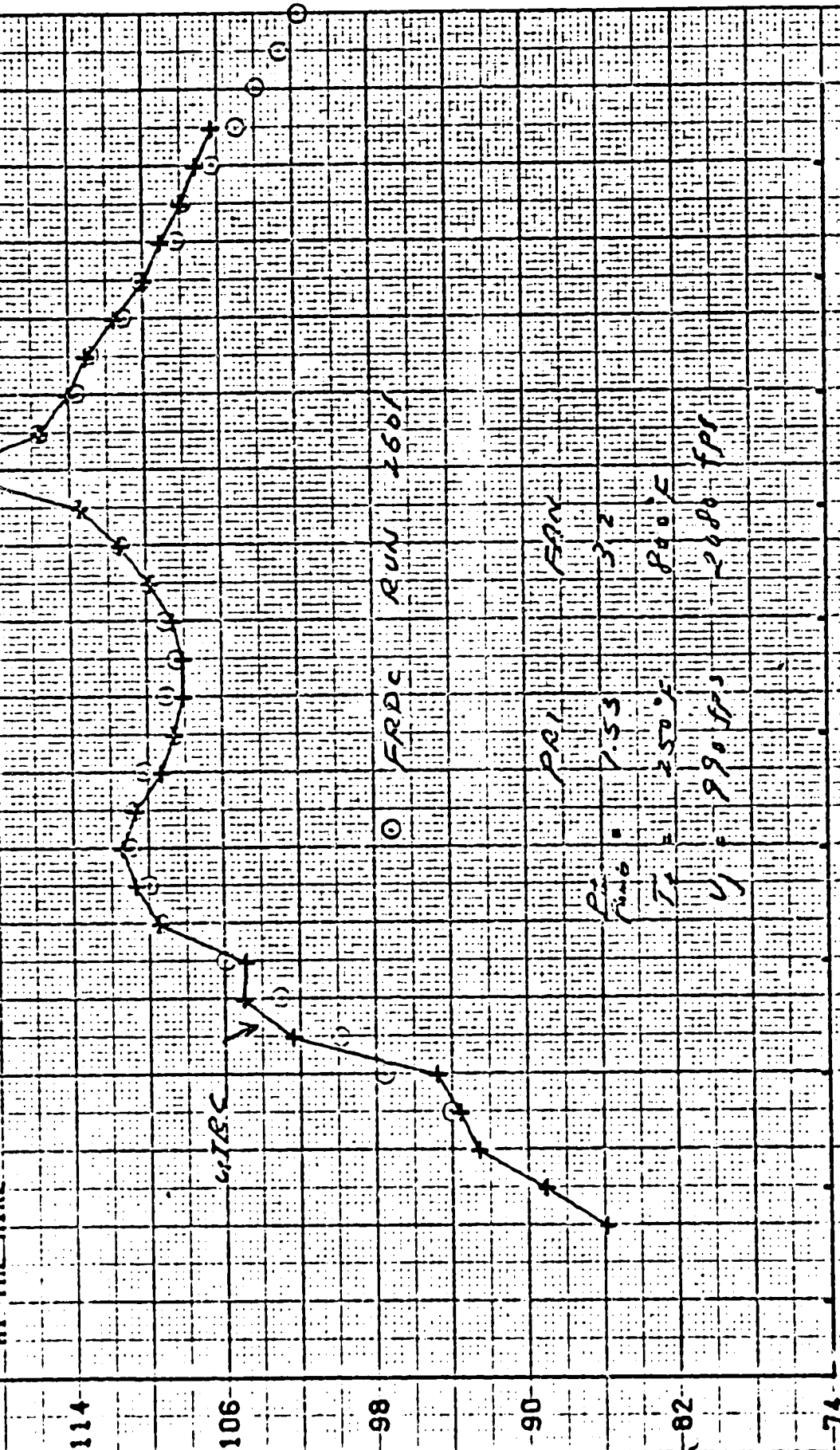
63 125 250 500 1K 2K 4K 8K 16K 32K 64K

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

20033F DBTF JET NOISE TEST CORNULAR NO2 AR=0.76 CONF 2 TAPE 4222 10.2049

122 MICROPHONE ANGLE = 150 DEO
ENGINE CONDITION = 9301
AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

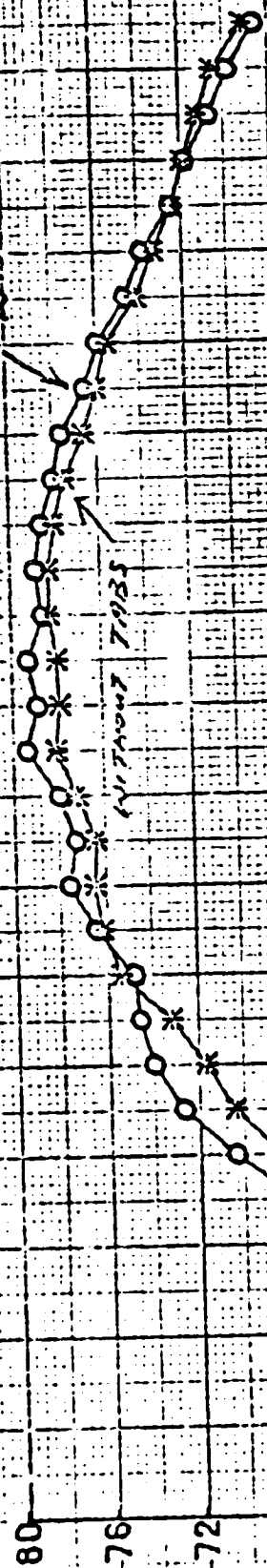


CONVERGENT NOZZLE

O COND 3662 DEG 90 * COND 1831 DEG 90

WITH 7985

WITHOUT 7935



$$\frac{P_2}{P_{20}} = 1.3$$

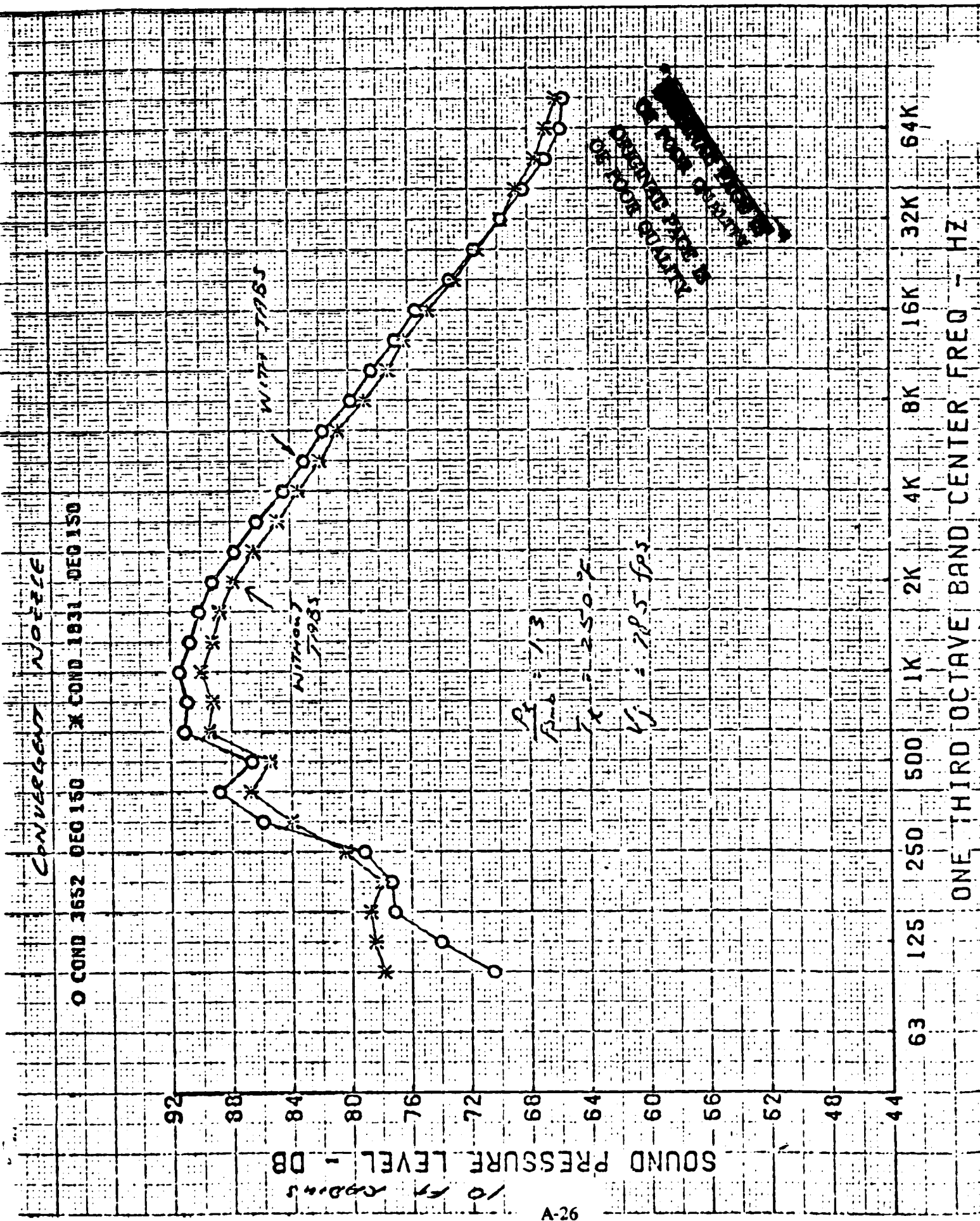
$$T_2 = 250^\circ \text{F}$$

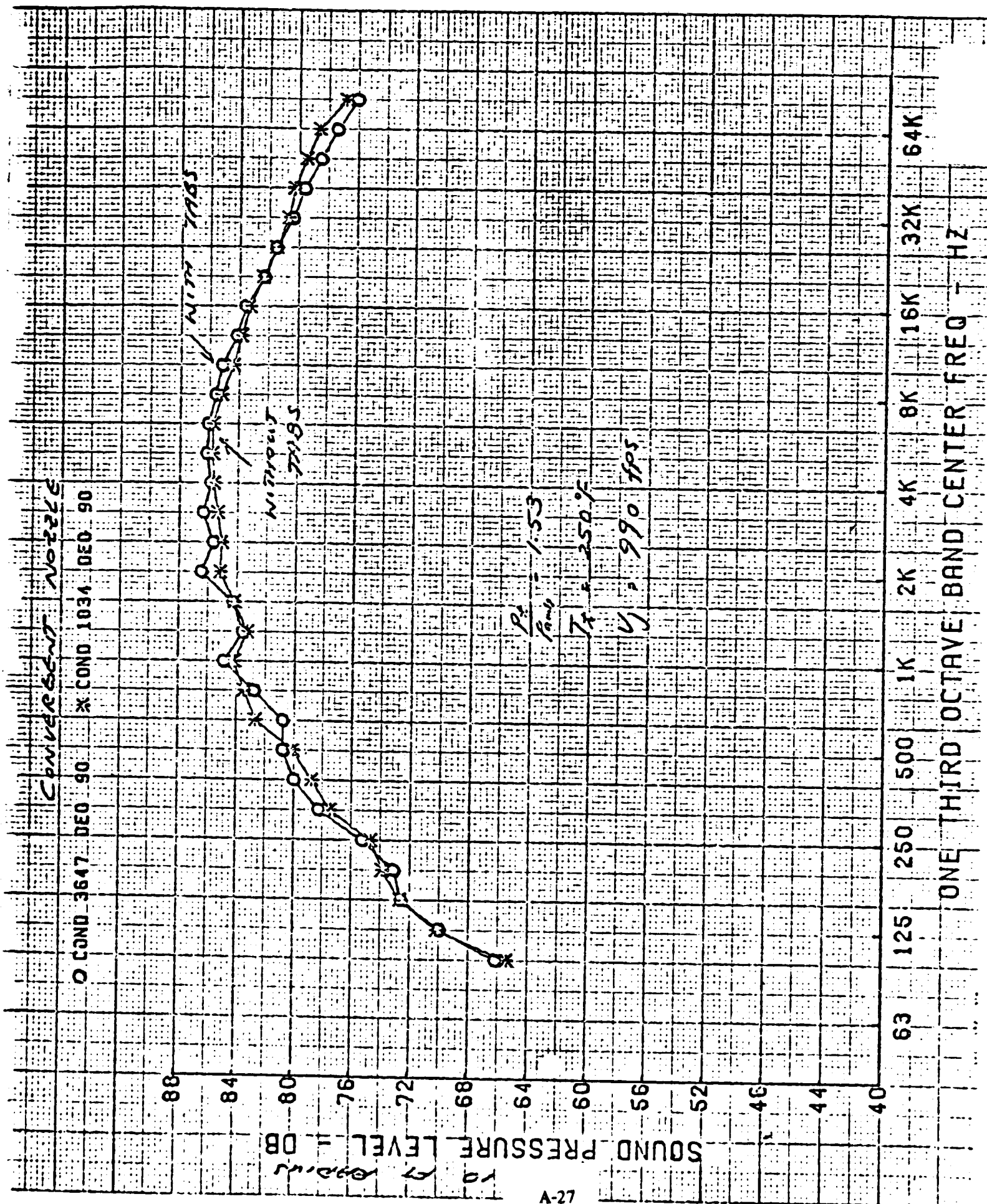
$$V_2 = 785 \text{ FPS}$$

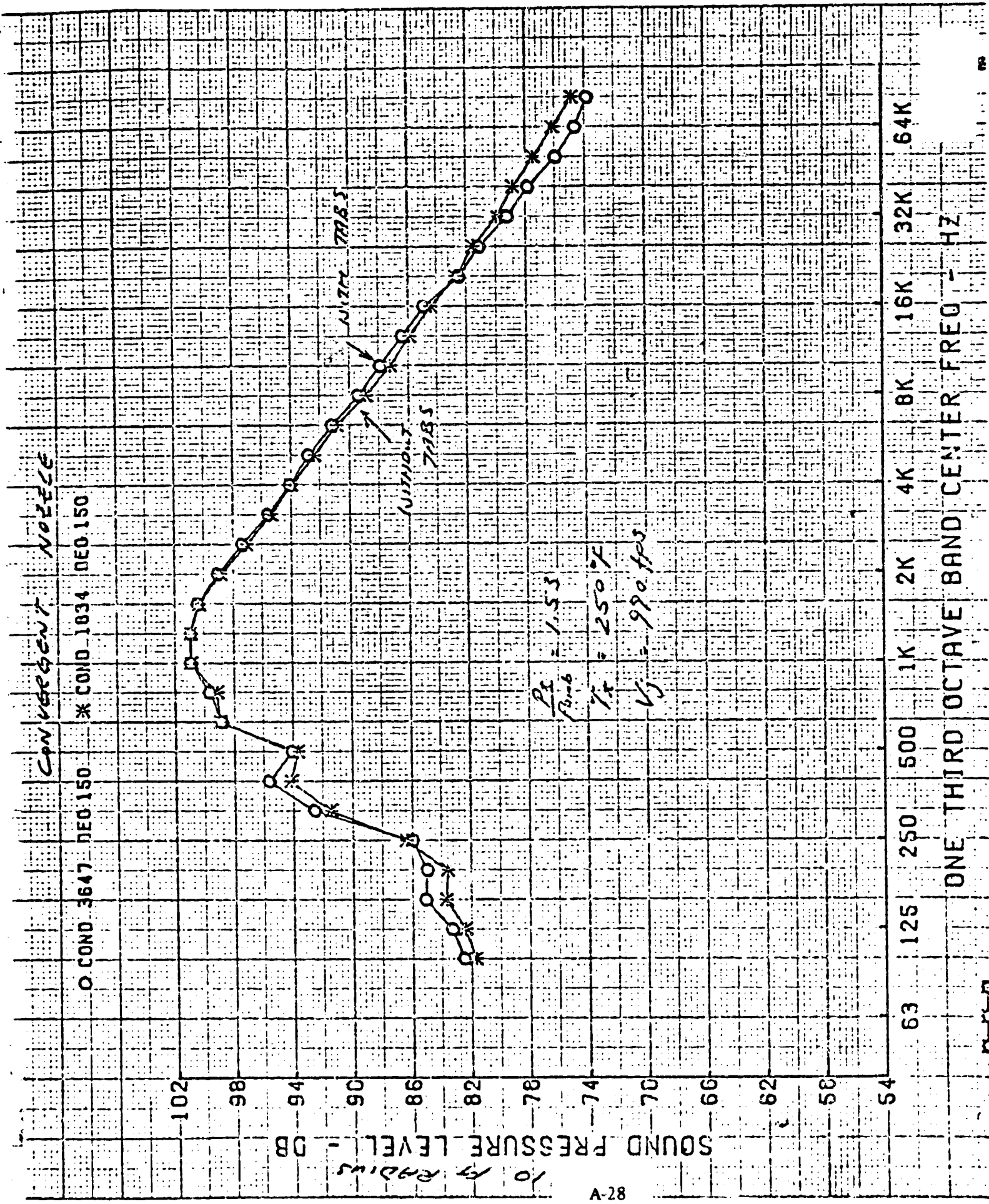
10 X RADII
SOUND PRESSURE LEVEL - DB

63 125 250 500 1K 2K 4K 8K 16K 32K 64K

ONE THIRD OCTAVE BAND CENTER FREQ - HZ

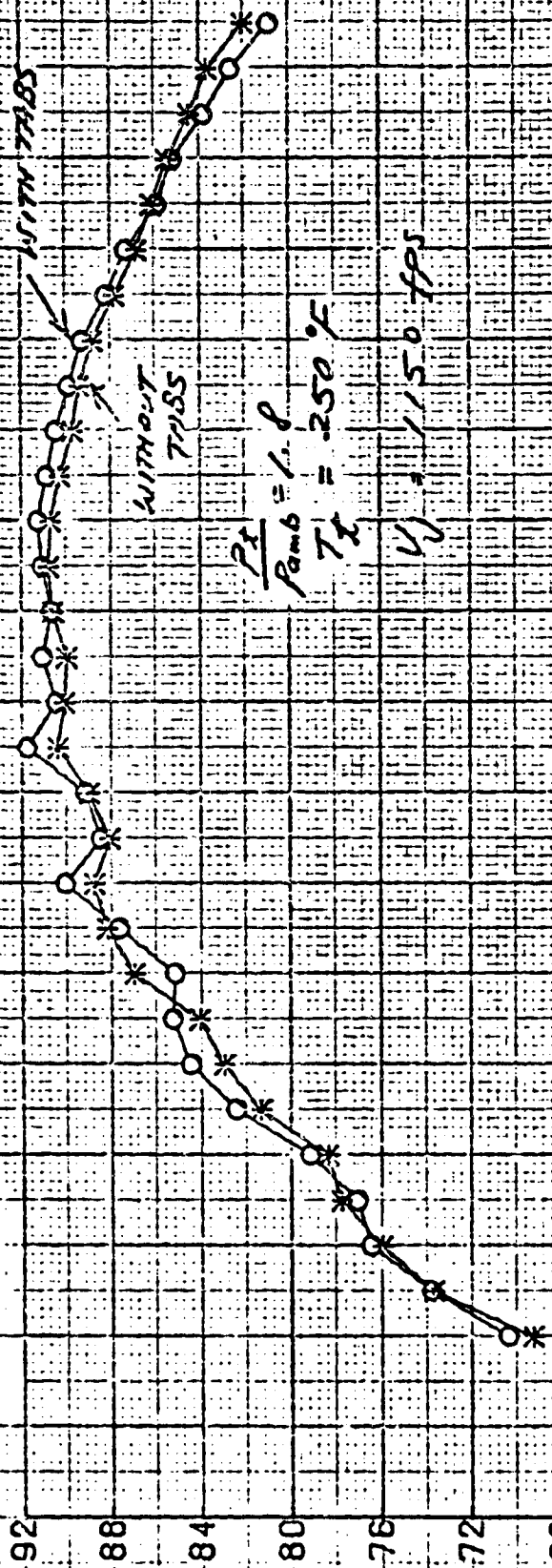






CONVERT TO Hz

O COND 3646 DEC 90 * COND 1837 DEC 90



10 ft Radius
SOUND PRESSURE LEVEL - DB

63 125 250 500 1K 2K 4K 8K 15K 32K 64K

ONE THIRD OCTAVE BAND CENTER FREQ - HZ

10 FT RADII
SOUND PRESSURE LEVEL - DB

CONVERT NOISE

* COND 1837 DEC 160

* COND 160 DEC 160

O COND 3646 DEC 160

WITH TAILS

WITHOUT TAILS

$P_2 = 1.8$

$P_{200} = 1.8$

$T_2 = 250^\circ F$

$V_2 = 1150 \text{ fms}$

ONE THIRD OCTAVE BAND CENTER FREQ - HZ

64K

32K

16K

8K

4K

2K

1K

500

250

125

63

62

66

70

74

78

82

86

90

94

98

102

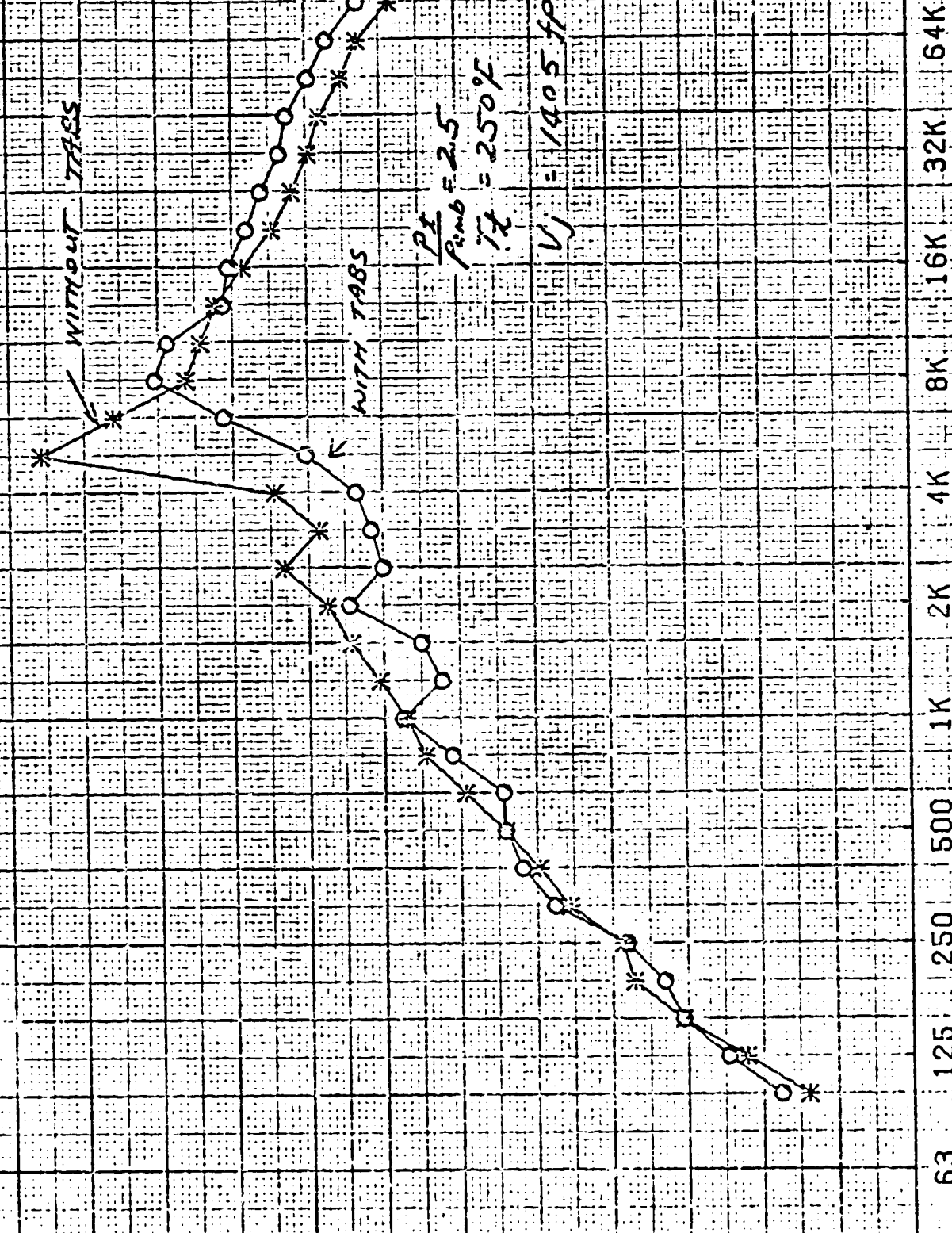
106

110

CONVERGENT NOZZLE

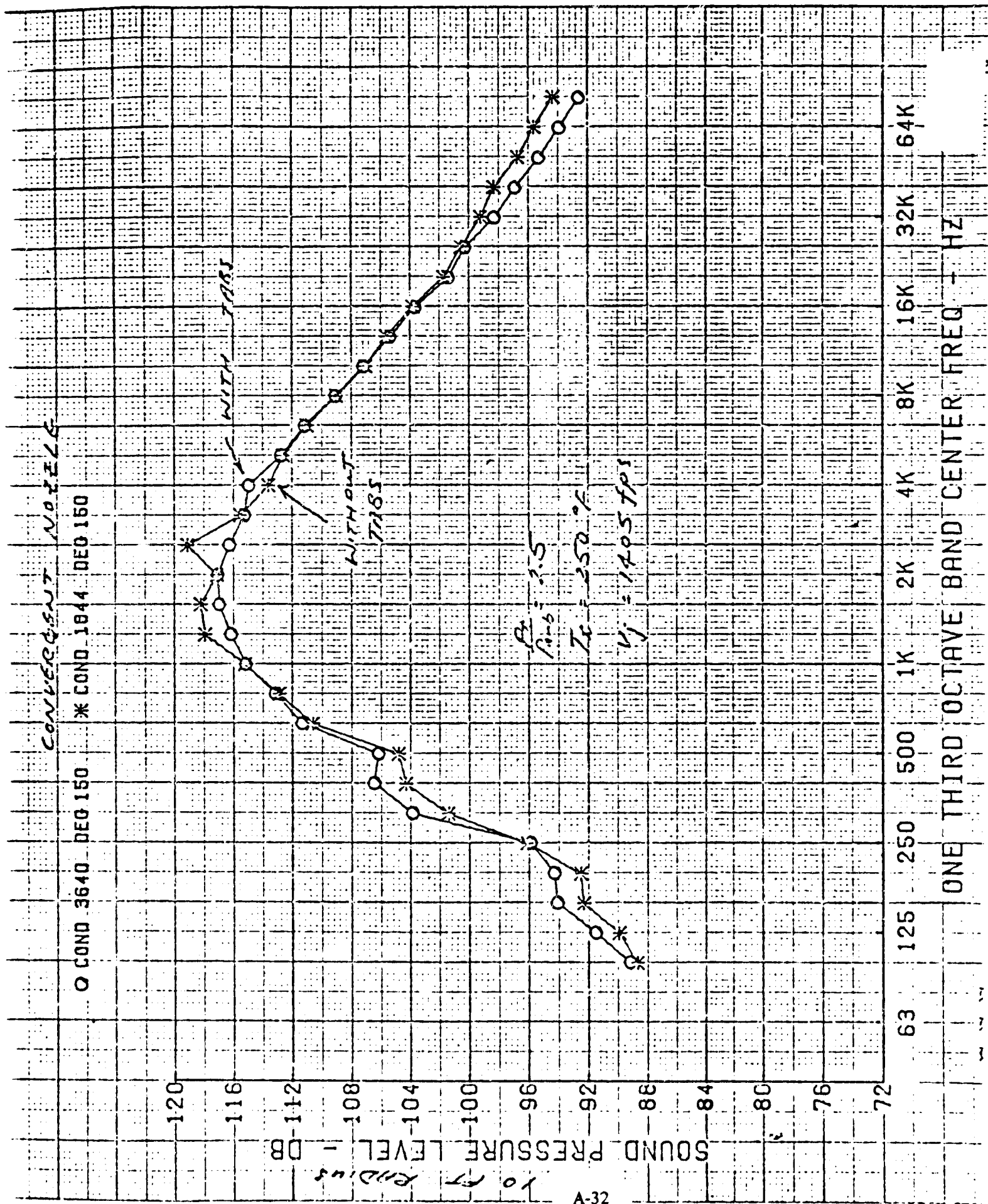
O COND 3640 DEG 90 * COND 1844 DEG 90

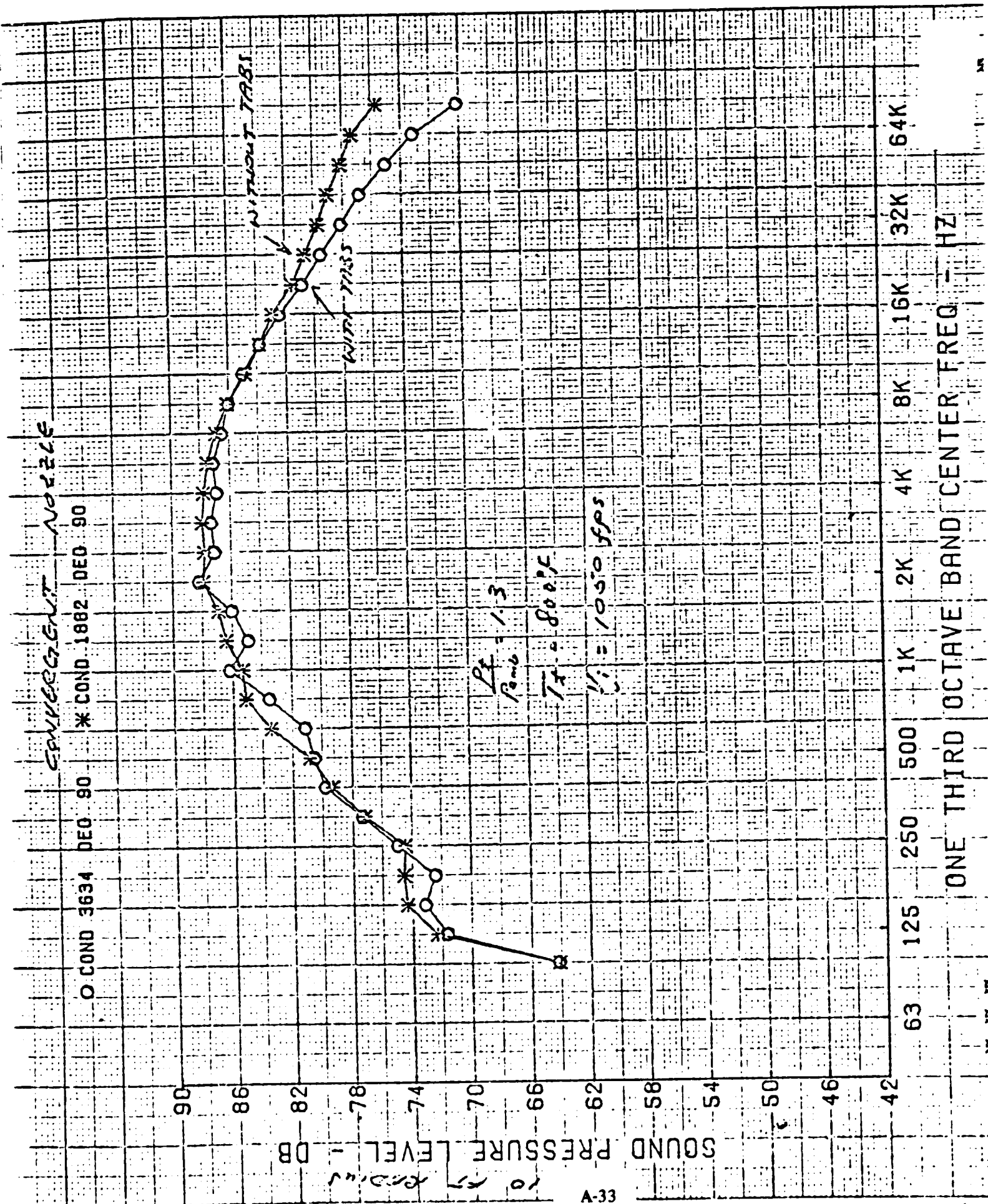
10 FT Radius
SOUND PRESSURE LEVEL - DB

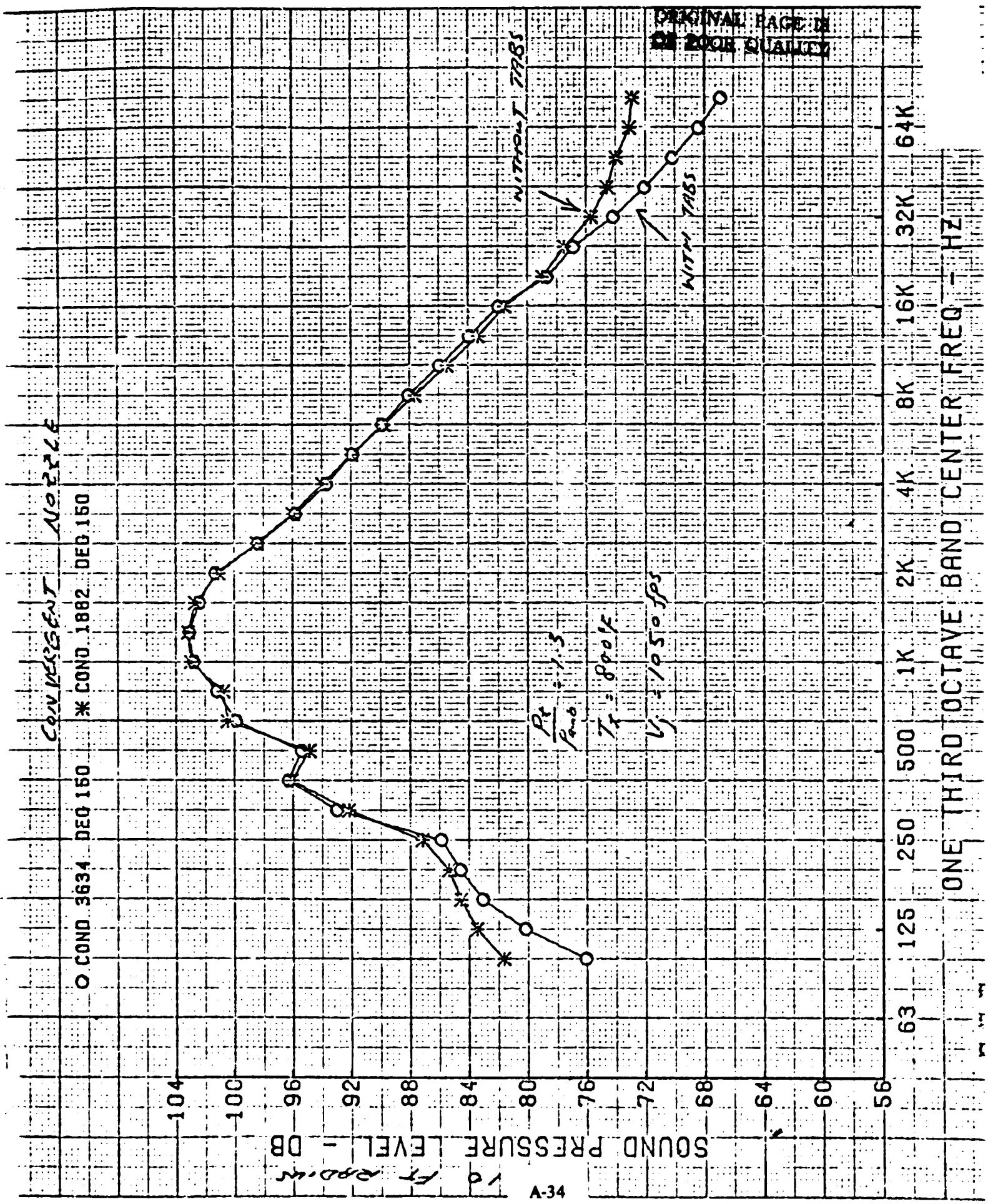


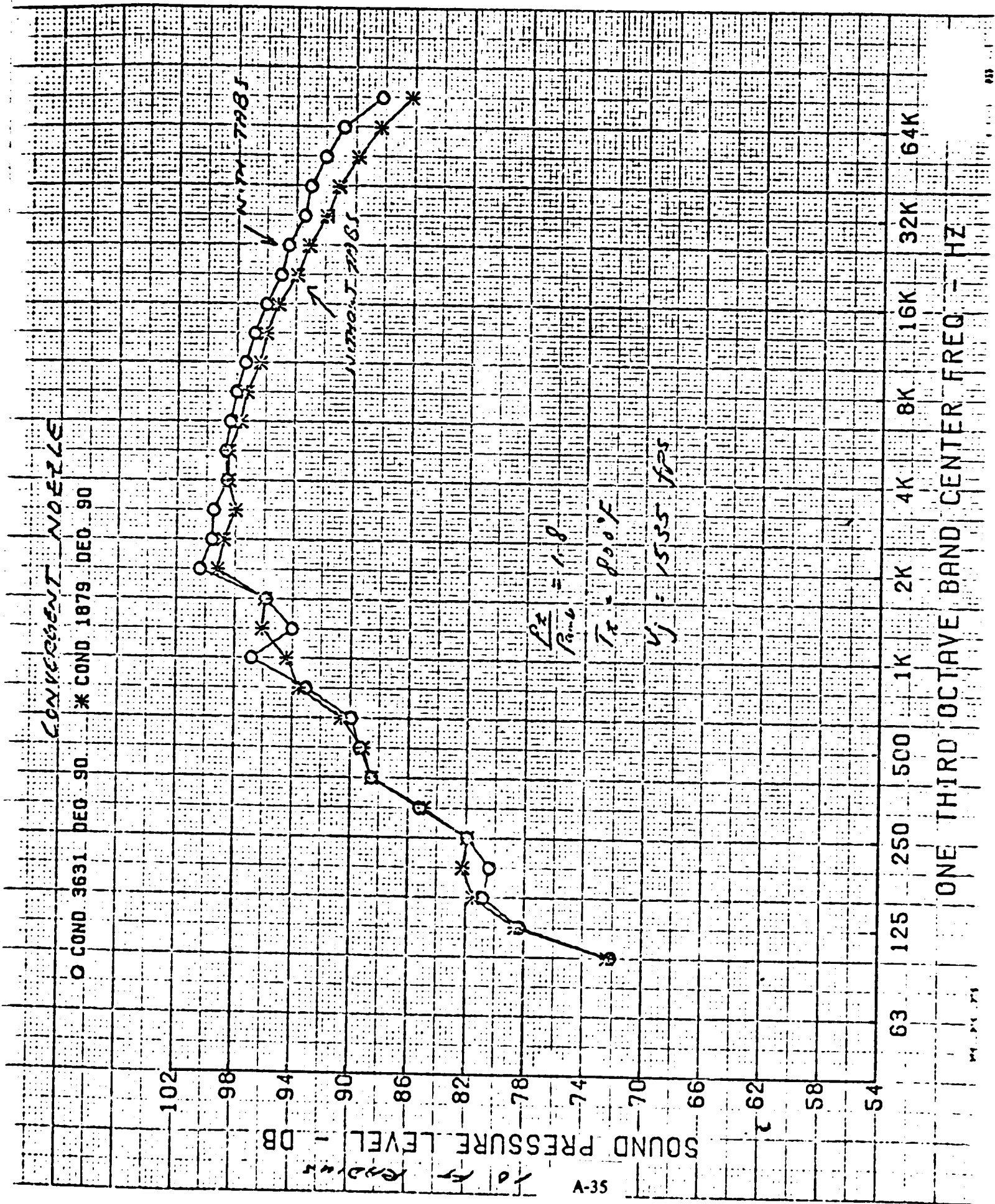
ORIGINAL PAGE IS
OF POOR QUALITY

ONE THIRD OCTAVE BAND CENTER FREQ - HZ









CONVERGENT NOISE

O COND 3631 DEO 150 * COND 1879 DEO 150

10 FT READINGS
SOUND PRESSURE LEVEL - DB

118
114
110
106
102
98
94
90
86
82
78
74
70

63 125 250 500 1K 2K 4K 8K 16K 32K 64K

ONE THIRD OCTAVE BAND CENTER FREQ - HZ

WITH TH35
WITHOUT TH35

$\frac{P_2}{P_{2wb}} = 1.8$

$T_x = 800^\circ F$

$U = 1535 \text{ FPS}$

CONCURRENT NOISE

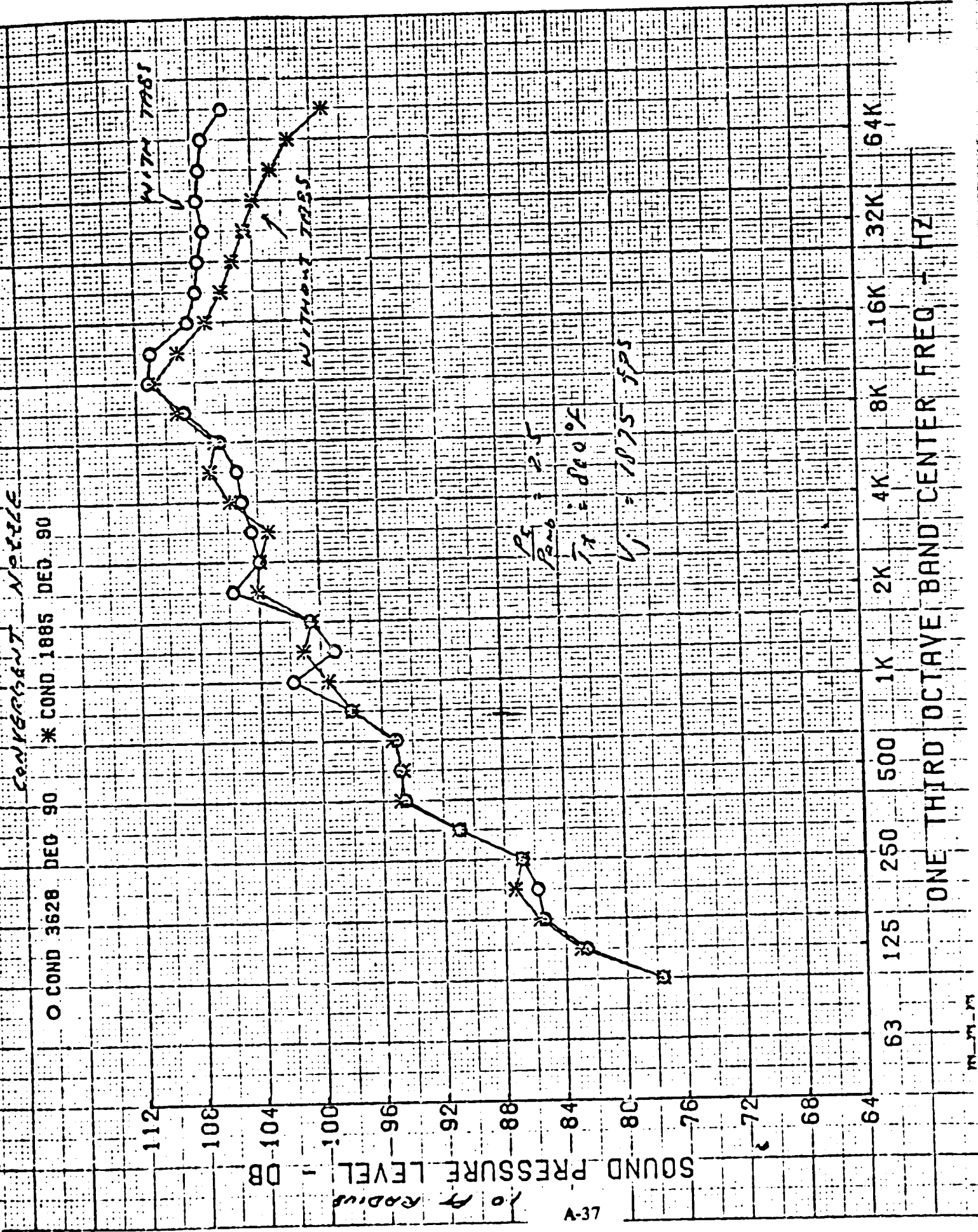
O COND 3628 DEC 90 * COND 1885 DEC 90

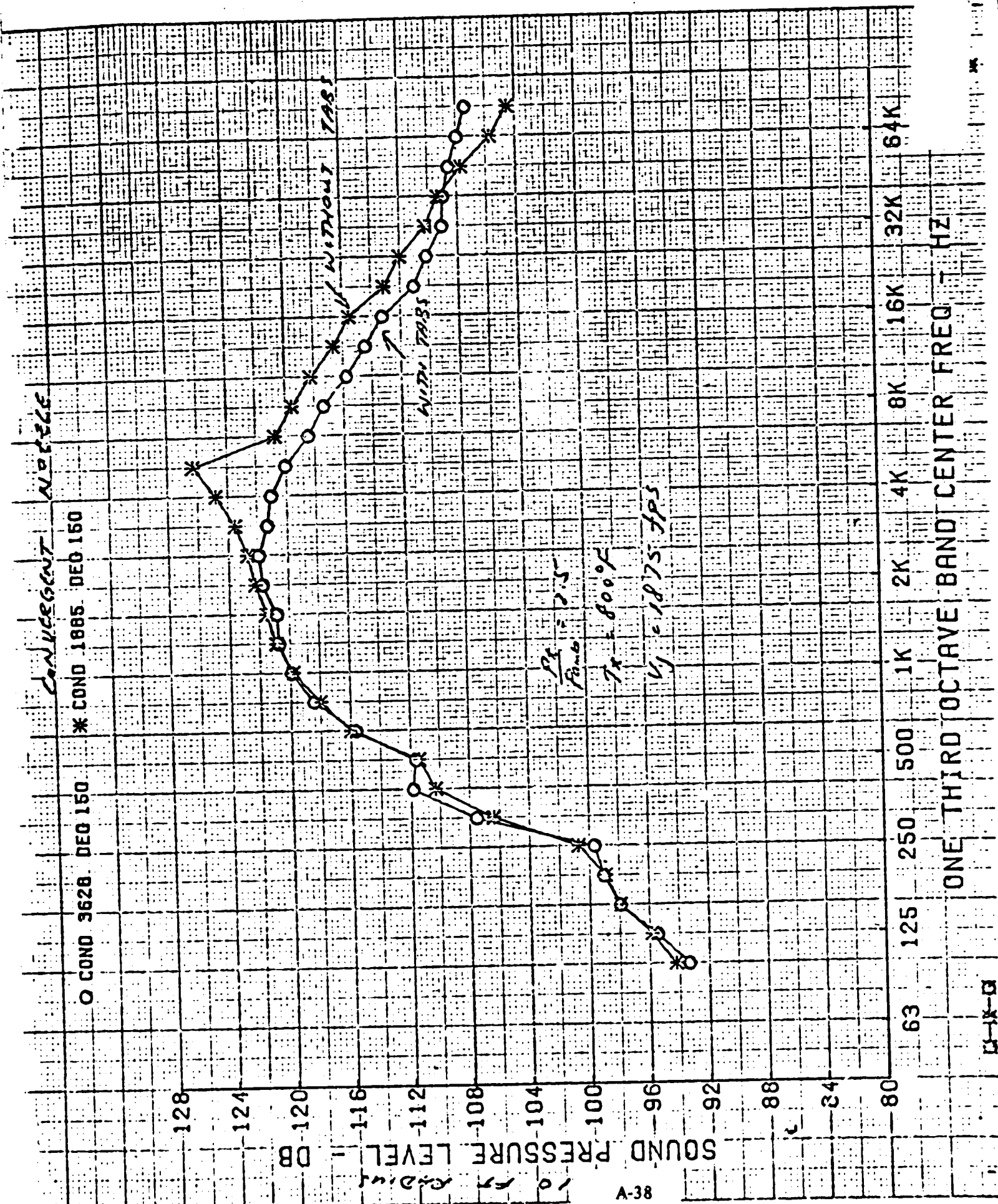
WITH TAPS
WITHOUT TAPS

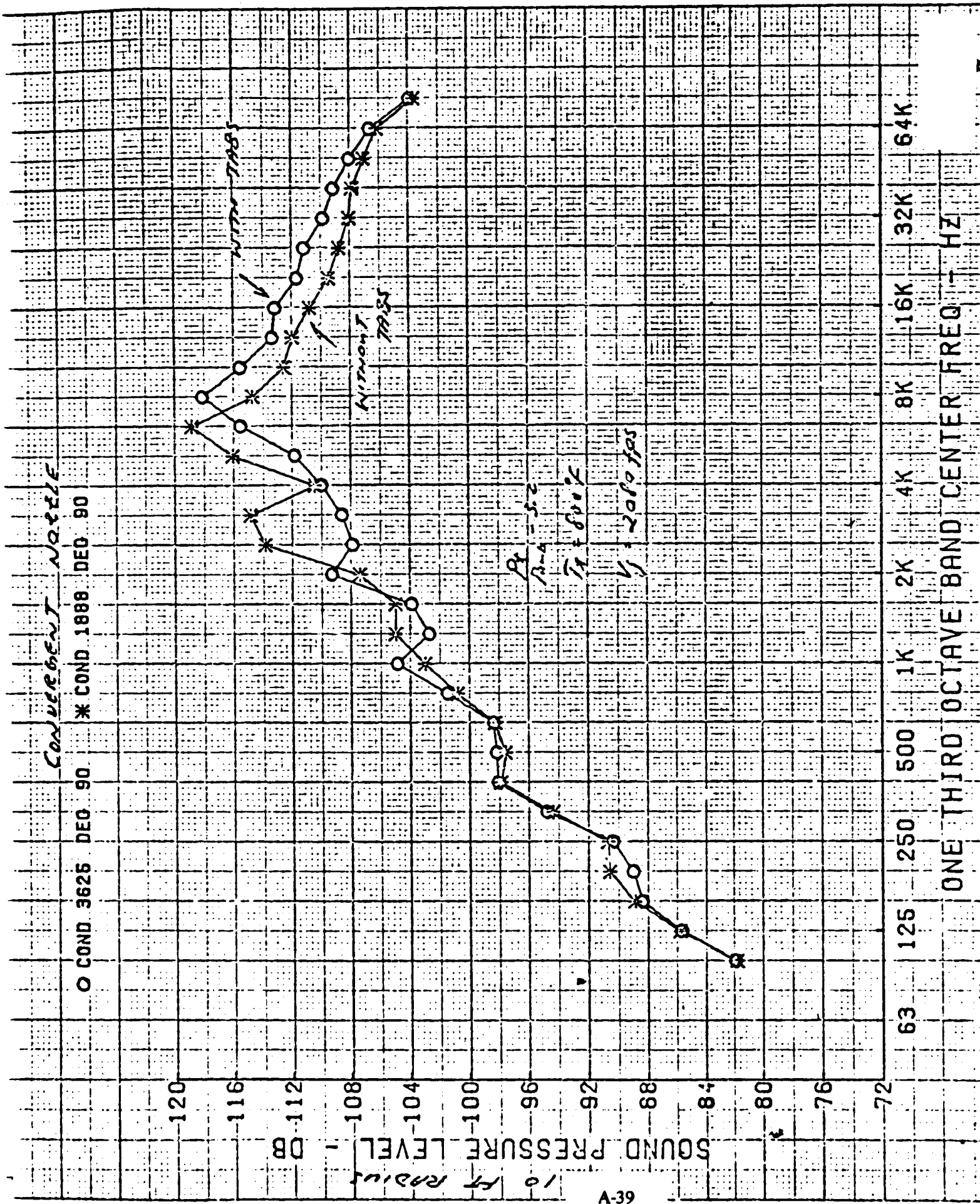
P_5
 $P_{avg} = 2.5$
 $T_x = 800^\circ F$
 $V_j = 1875 \text{ FPS}$

10 ft Radius
SOUND PRESSURE LEVEL DB

ONE THIRD OCTAVE BAND CENTER FREQ - HZ





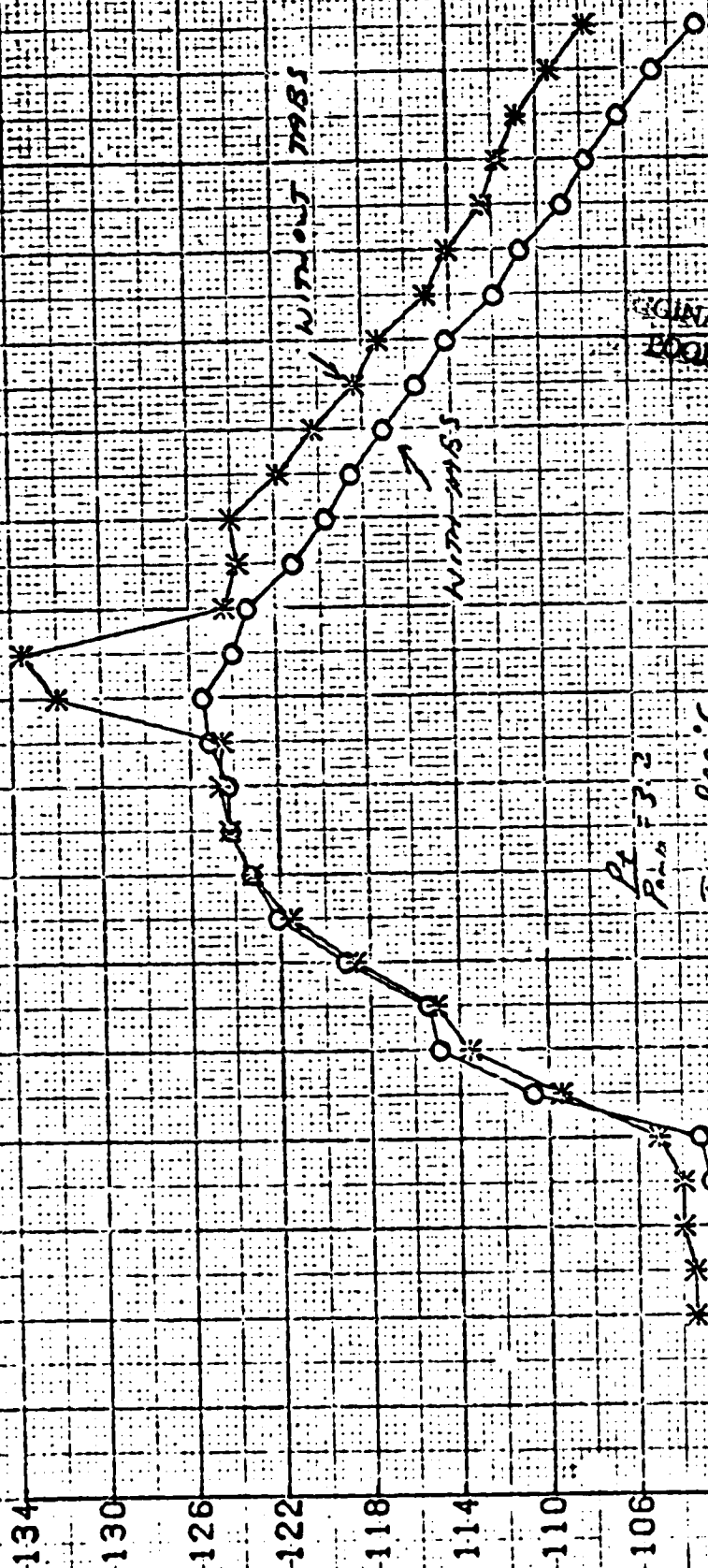


CONVERGENT NOISE

O COND 3625 DEQ 150 * COND 1088 DEQ 150

SOUND PRESSURE LEVEL - DB

10 ft radius A40



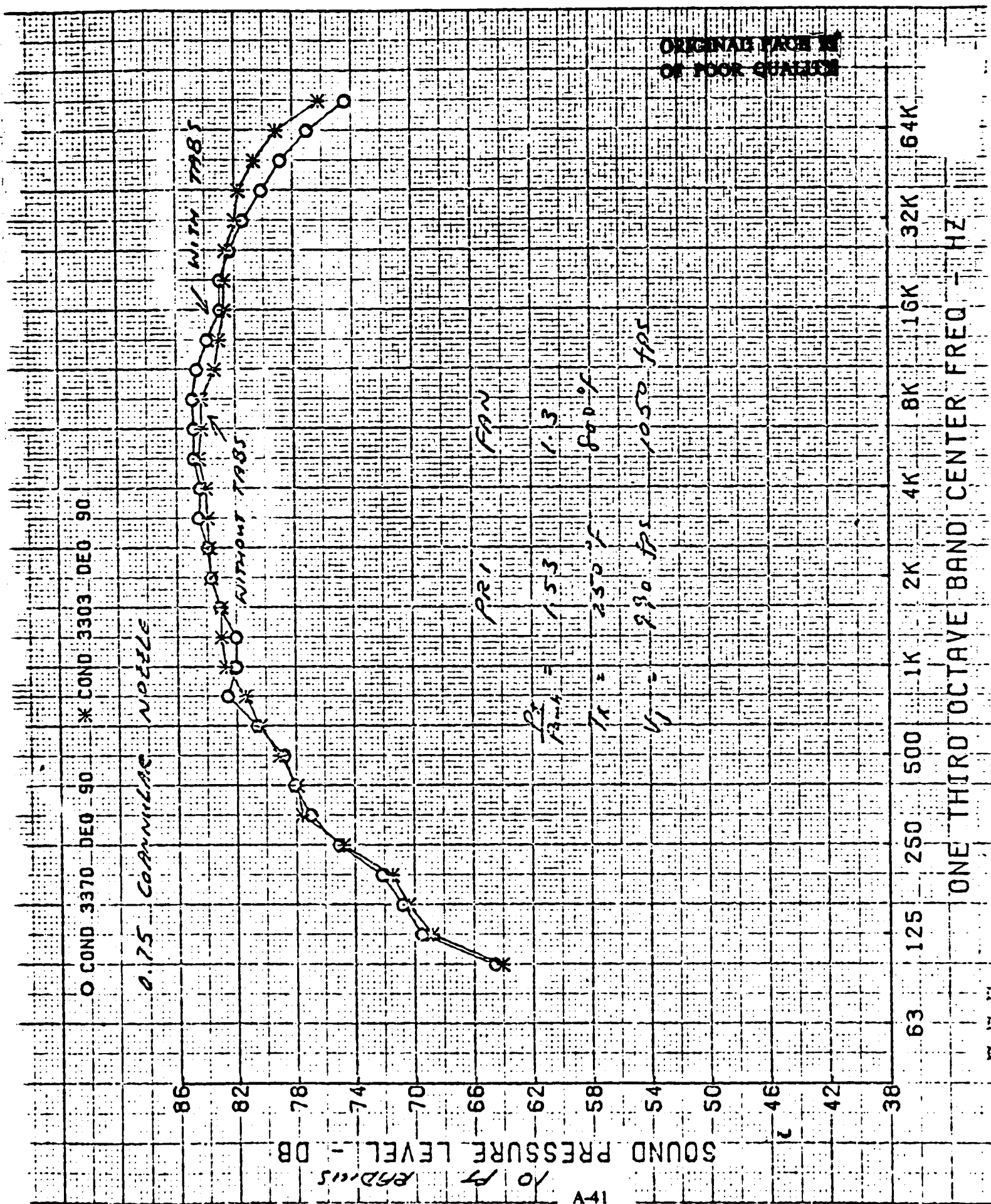
PE = 3.2

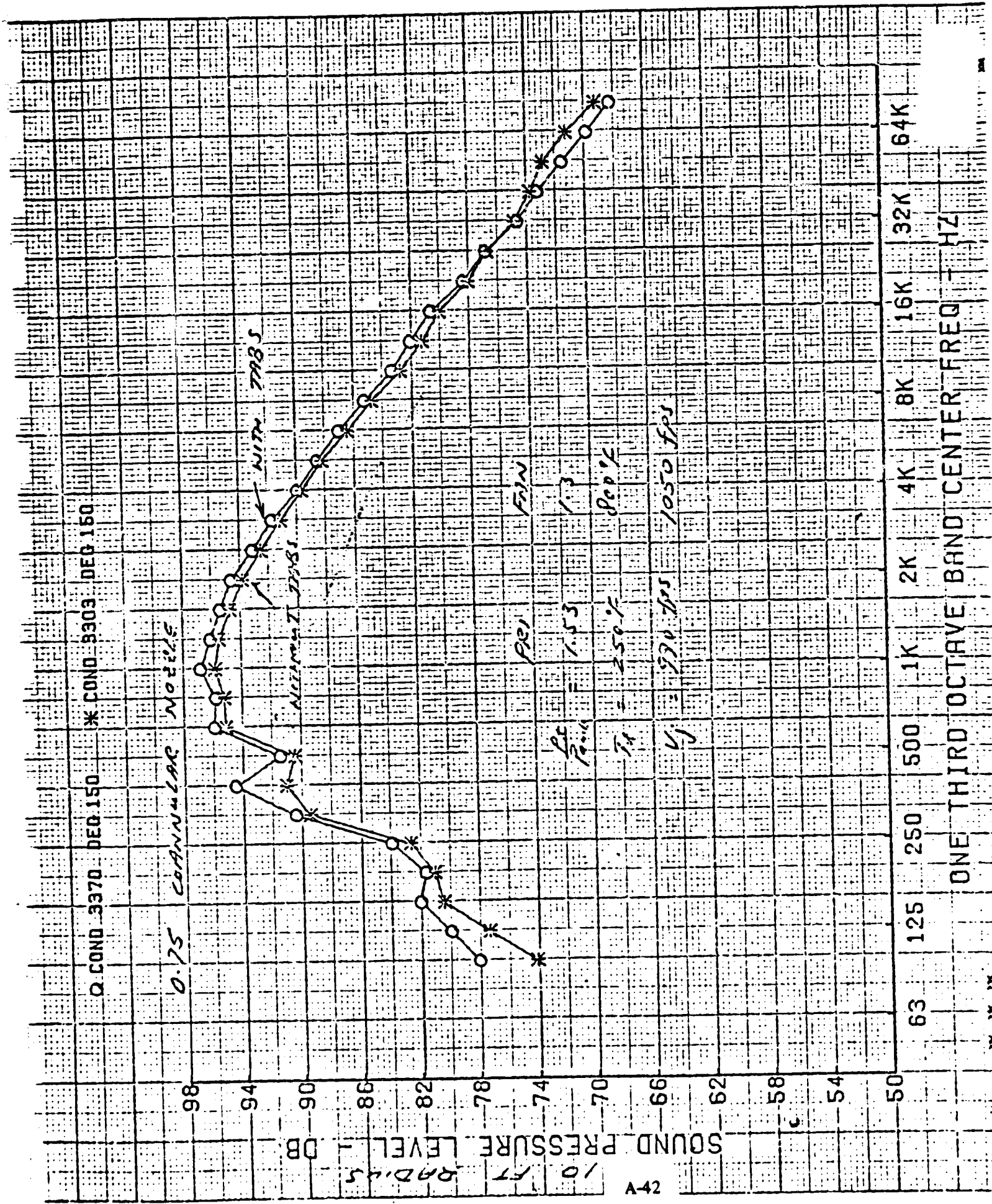
T₁ = 800 f

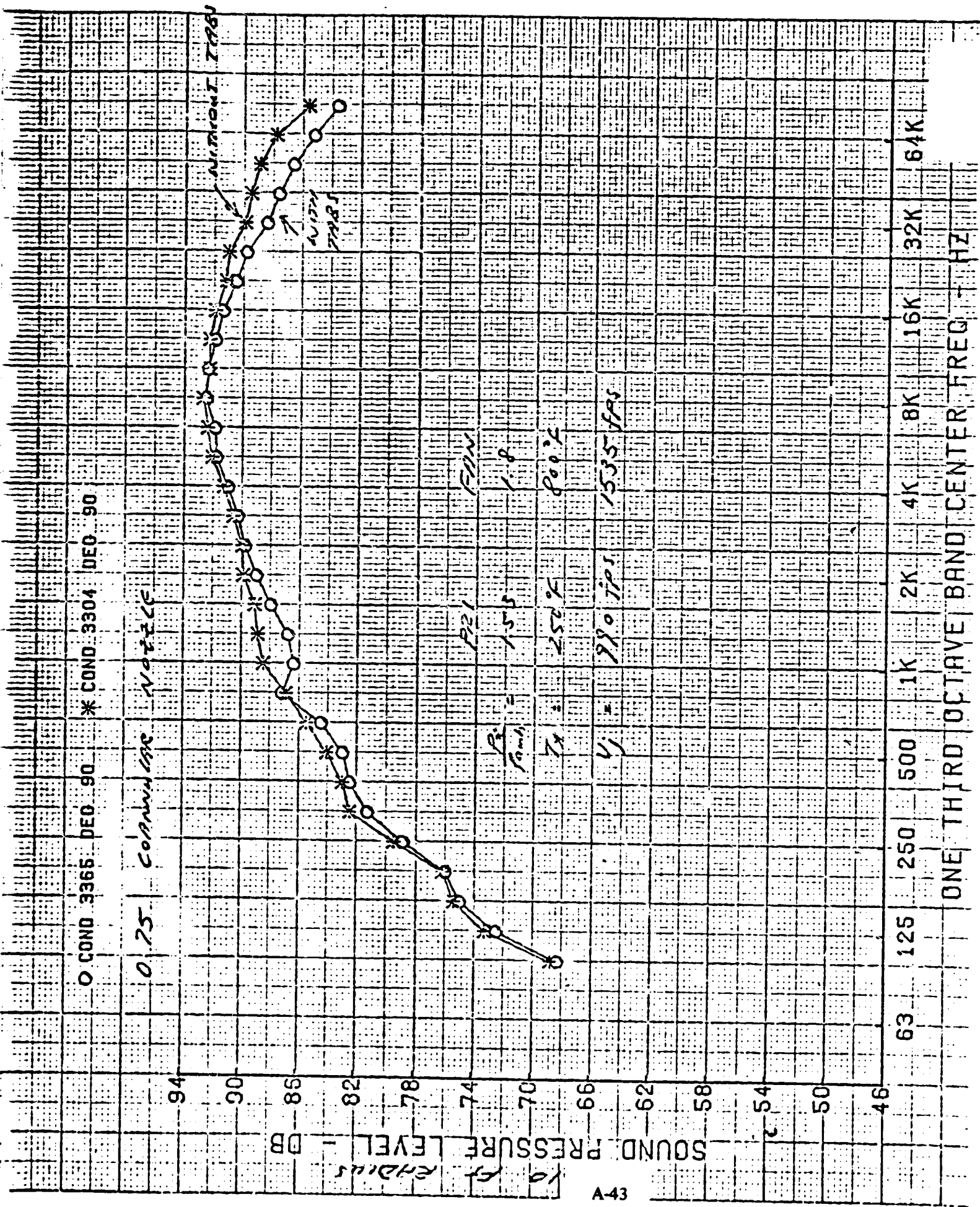
V₁ = 2080 fps

EQUIV. P. 2000

ONE THIRD OCTAVE BAND CENTER FREQ. - HZ



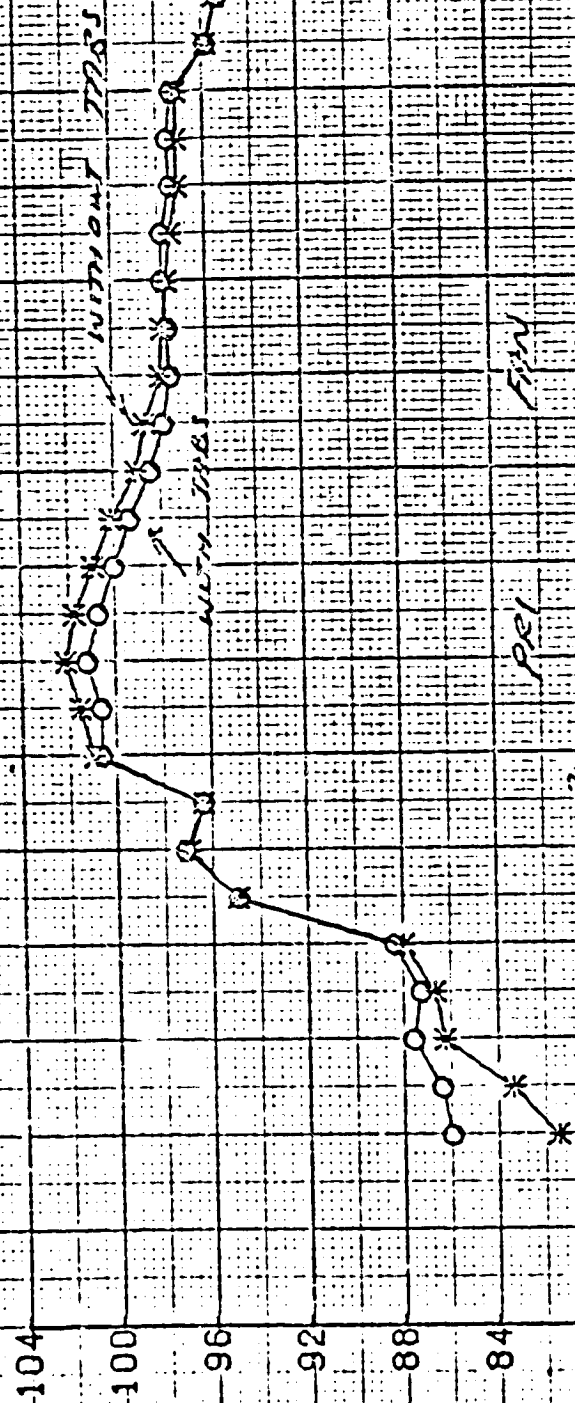




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OF POOR QUALITY

O COND 3365 DEQ 150 * COND 3304 DEQ 150

0.75 CORNULUS NOISE



SOUND PRESSURE LEVEL - DB

ONE THIRD OCTAVE BAND CENTER FREQ - HZ

10 FT PRESSURE
SOUND PRESSURE LEVEL - DB

O COND 3364 DEG 90 * COND 3302 DEG 90

0.25 CORRECTION NEARLY

WITH 2.5% LOSS

WITH 2.5% LOSS

921

$f_{max} = 153$

2.5

800%

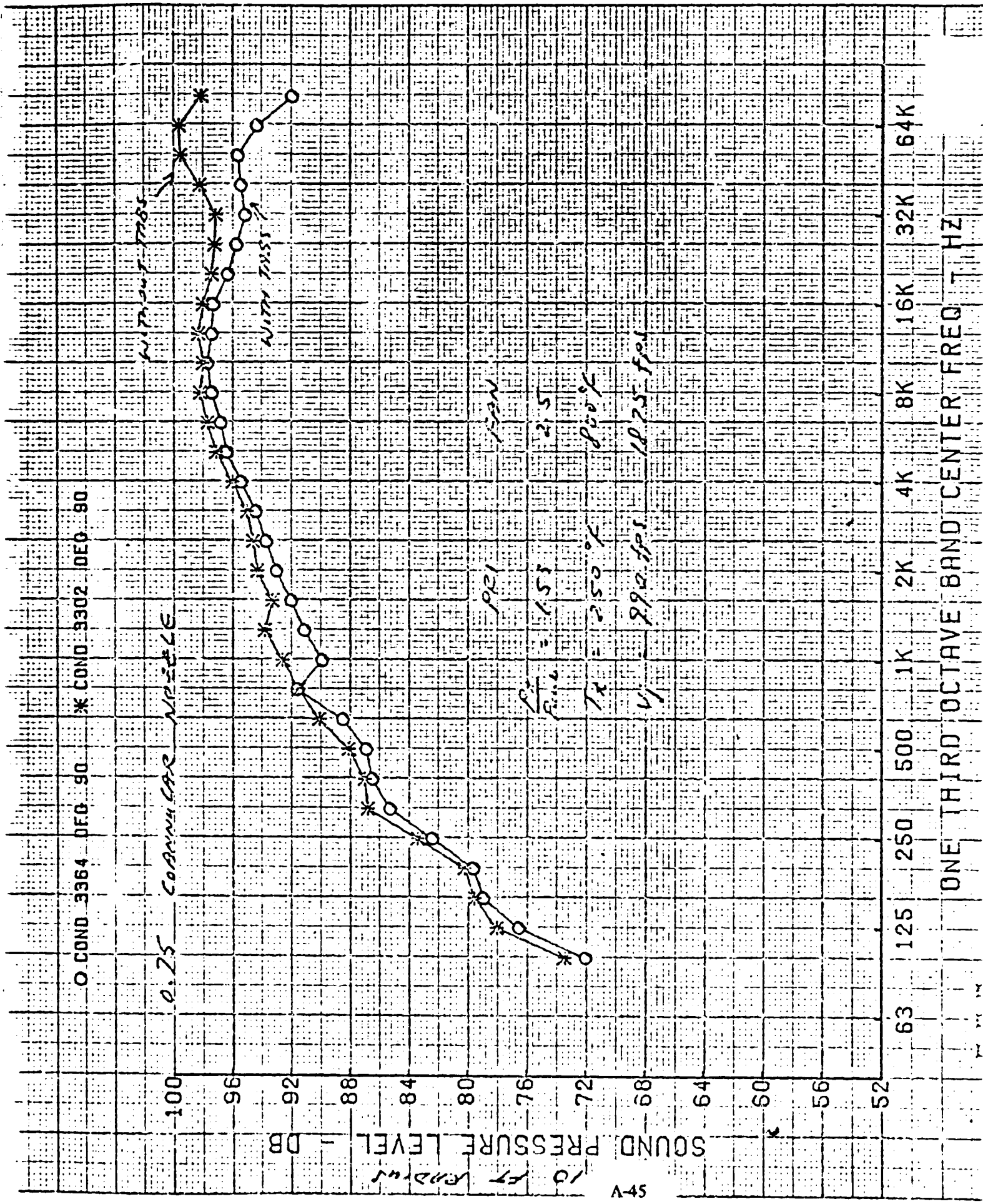
$T_k = 250^\circ F$

$V_f = 990 \text{ fps}$

1875 fpi

63 125 250 500 1K 2K 4K 8K 16K 32K 64K

ONE THIRD OCTAVE BAND CENTER FREQ T HZ



ORIGINAL PAGE IS
OF POOR QUALITY

0.75 CONICAL NOZZLE

without TAPS

with TAPS

COND 3364 COND 3302 COND 150

112
108
104
100
96
92
88
84
80
76
72
68
64

1000
100
10
1

Hz

153
250
990
800°F
1875°F

P1
P2
P3
T1
T2
T3

COND 3364 COND 3302 COND 150

112
108
104
100
96
92
88
84
80
76
72
68
64

1000
100
10
1

Hz

153
250
990
800°F
1875°F

P1
P2
P3
T1
T2
T3

COND 3364 COND 3302 COND 150

COND	DEO	COND	DEO
3364	150	3302	150
* COND 3302 DEO 150			

37220N 36700000 5675

Two

7785

1000-2000

三

Pr.

2.55

三

2

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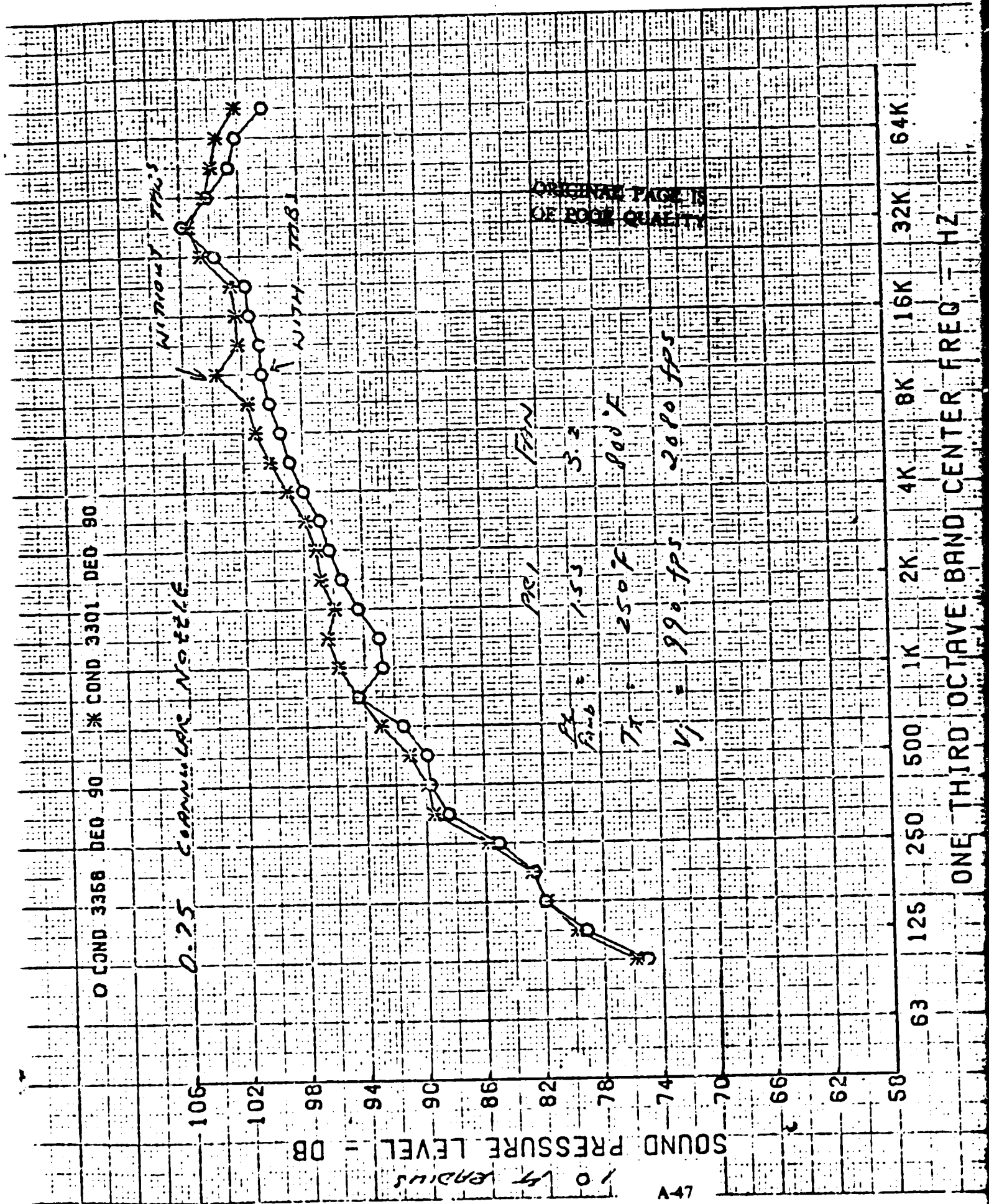
565-587

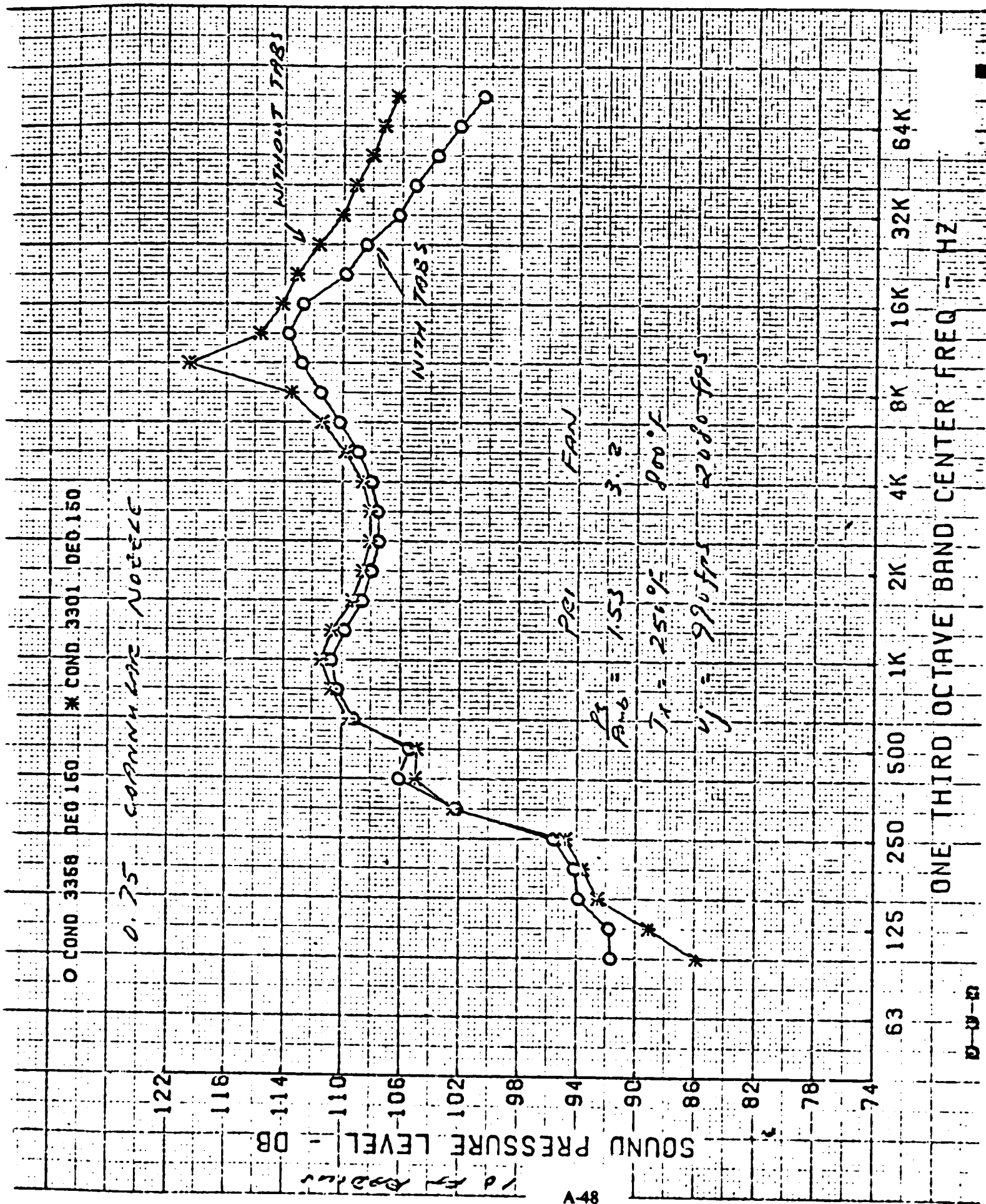
1875-40

۲۵۰۰ / ۲۵

A-46

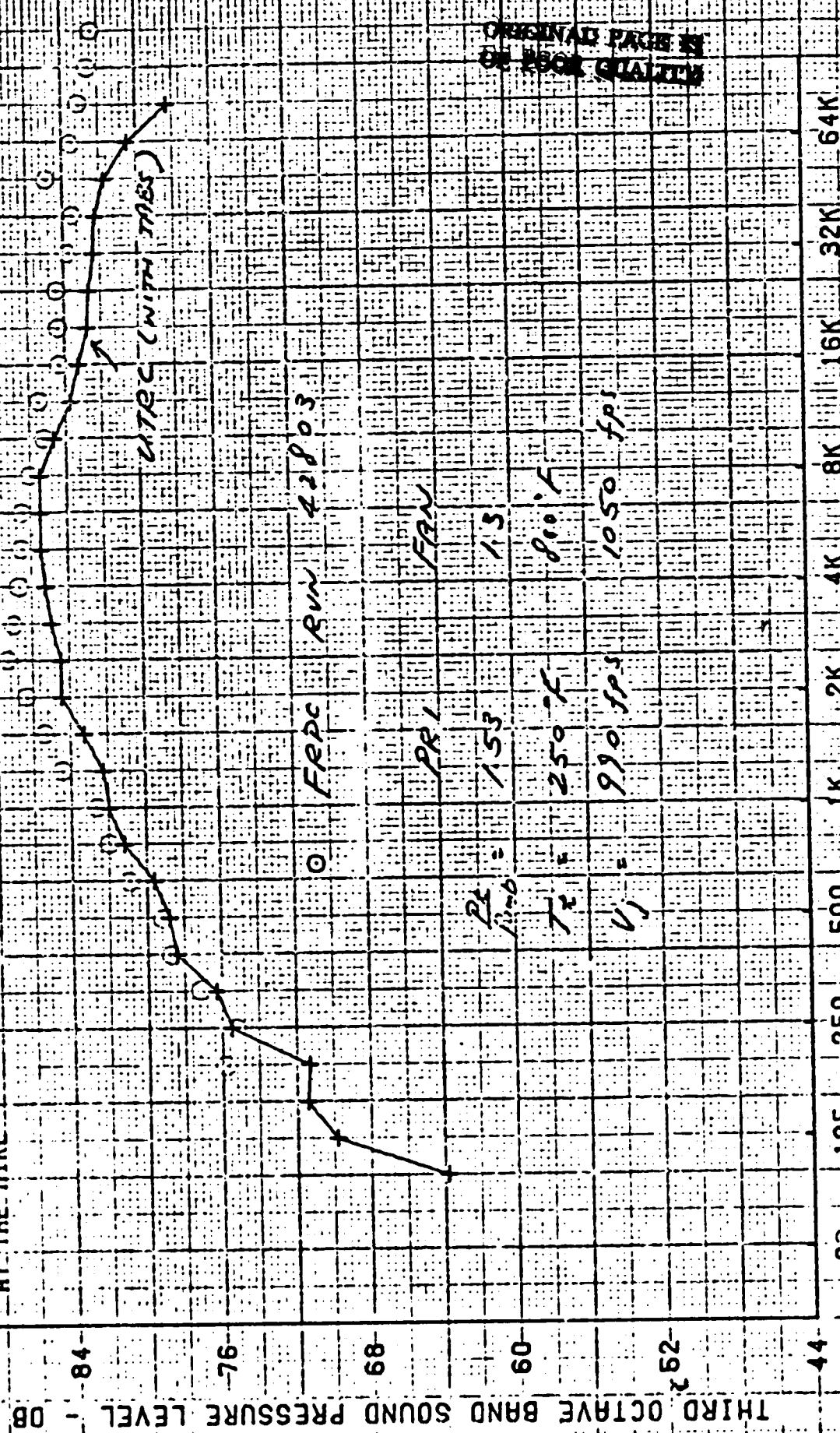
63	125	250	500	1K	2K	4K	8K	16K	32K	64K
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20034F DBT JET NOISE TEST CORNULAR NOZ AR=1.2 CONE 4 TAPE 4225 10.2049

MICROPHONE ANGLE = 90 DEO
 ENGINE CONDITION = 3413
 AT THE MIKE



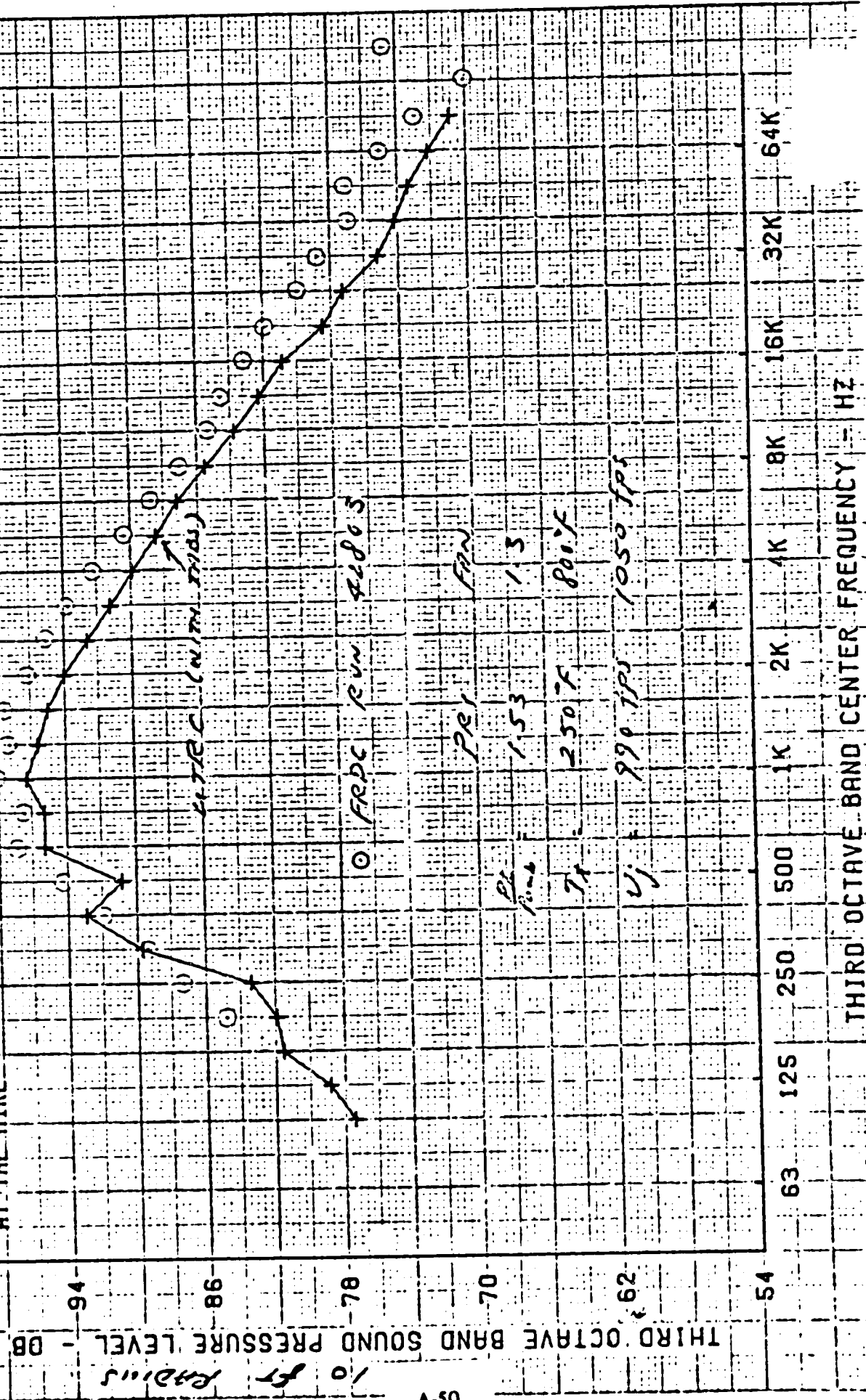
ORIGINAL PAGE 12
 OF 2800 QUALITY

PR = 1.53
 T_e = 250 °F
 V_j = 990 f/s

FAN

20034F DBIF JET NOISE TEST COANNULAR NOZ AR=1.2 CONF. 1 TAPE 4225 10.2049

MICROPHONE ANGLE = 150 DEG
 ENGINE CONDITION = 3413
 AT THE MIKE



20034F DBTF JET NOISE TEST CORNULAR NOZ. AR-1.2 CONF. 4 TAPE 4225 10.2049

MICROPHONE ANGLE = 90 DEG
 ENGINE CONDITION = 3408
 AT THE MIKE

UTRE (WITH TRS)

FRDC RUN 42802

ORIGINAL PAGE 1

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB

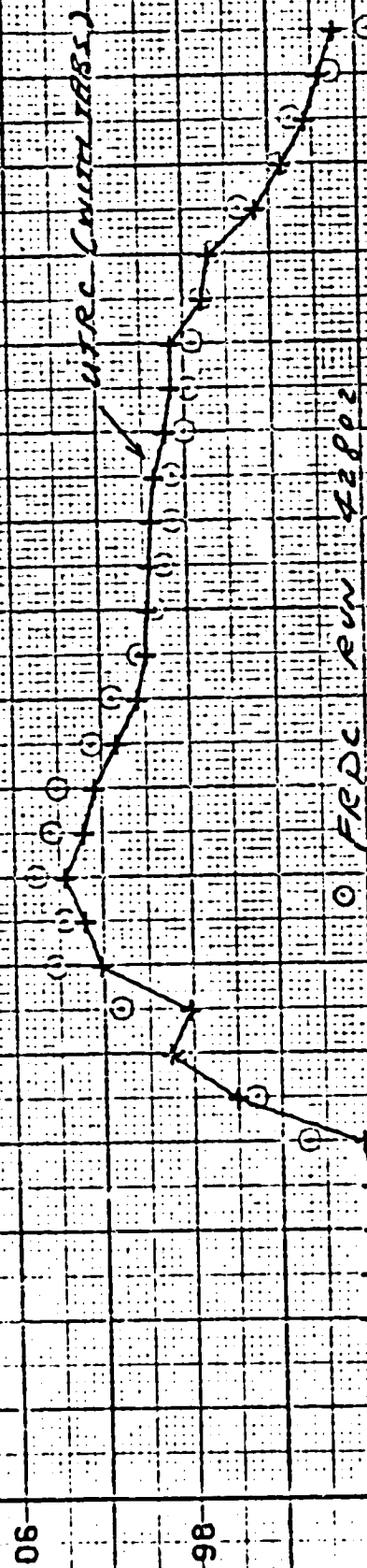
THIRD OCTAVE BAND CENTER FREQUENCY - HZ



20034F DB1F JET NOISE TEST CORNULAR NOZ. AR=L-2 CONF. 1 TAPE 4225 10, 2049

MICROPHONE ANGLE = 150 DEG
ENGINE CONDITION = 3408
AT THE MIKE

THIRD OCTAVE BAND SOUND PRESSURE LEVEL - DB



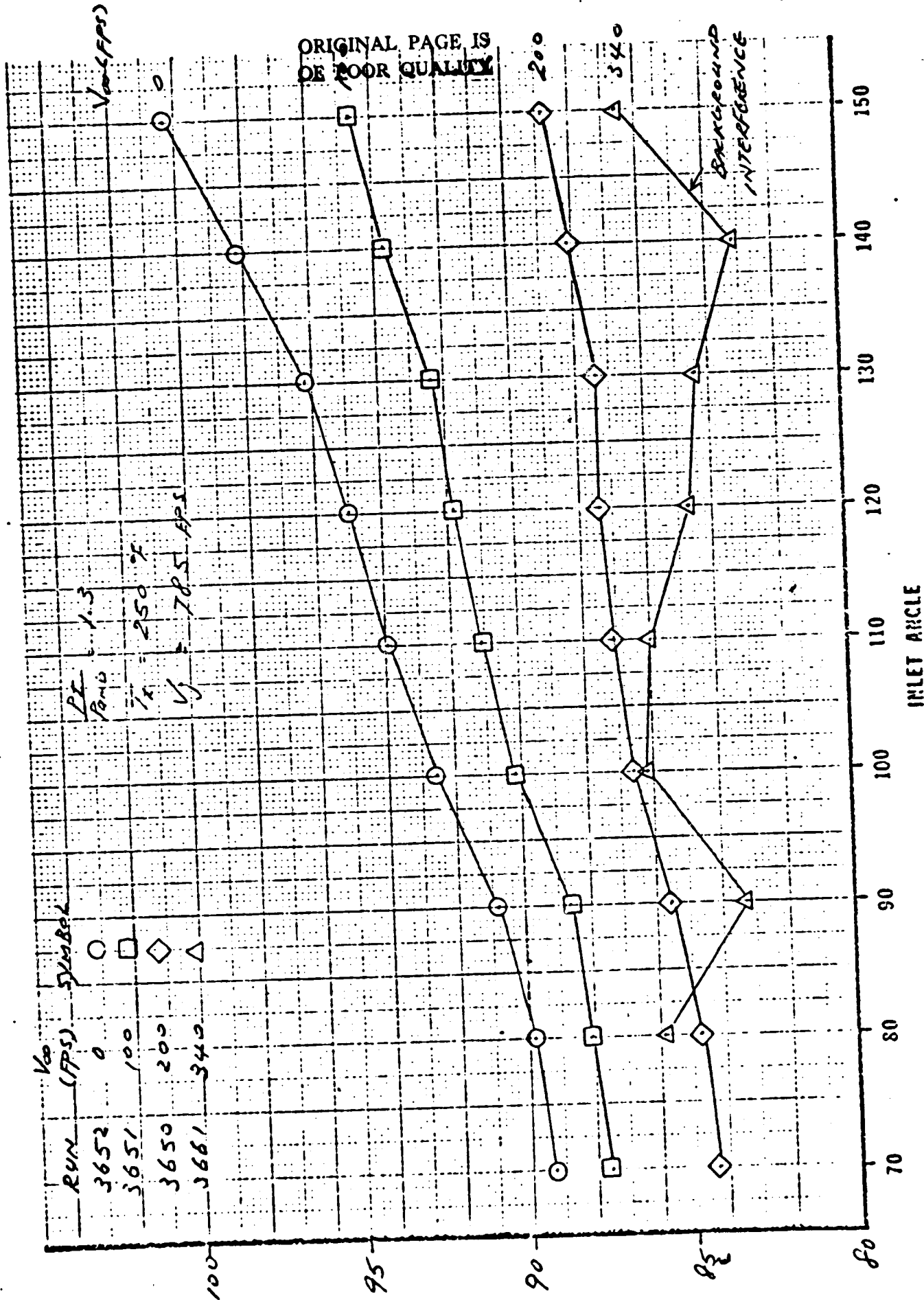
P_{r1}
 $P_{r2} = 1.53$
 $T_1 = 250^\circ F$
 $V_j = 220 \text{ FPS}$
 $V_j = 1535 \text{ FPS}$

THIRD OCTAVE BAND CENTER FREQUENCY - HZ

DIRECTIVITY

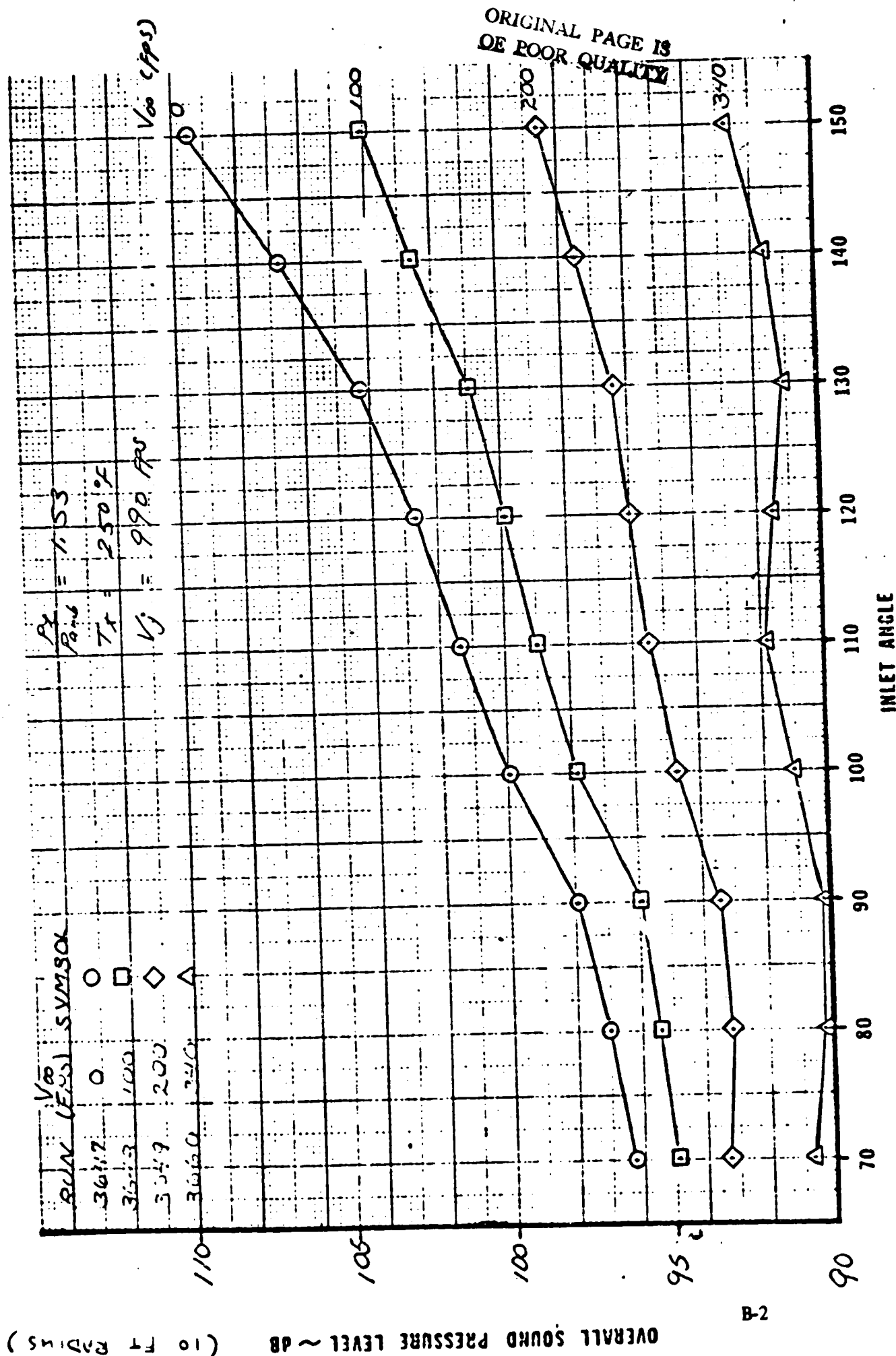
CONVERGENT NOZZLE

OVERALL SOUND PRESSURE LEVEL ~ 118 (10 FT RADIUS)



DIRECTIVITY

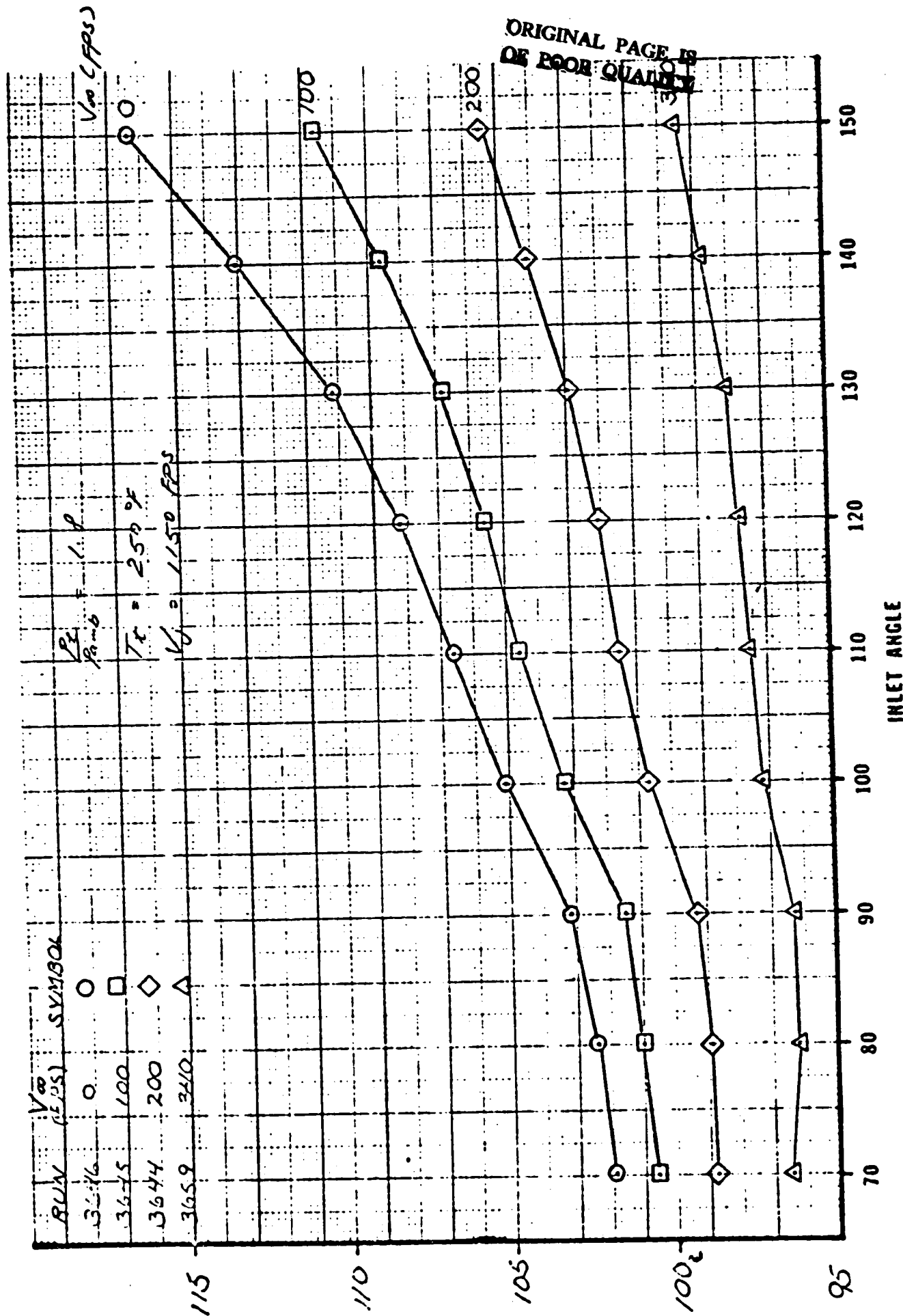
CONVERGENT NOZZLE



DIRECTIVITY

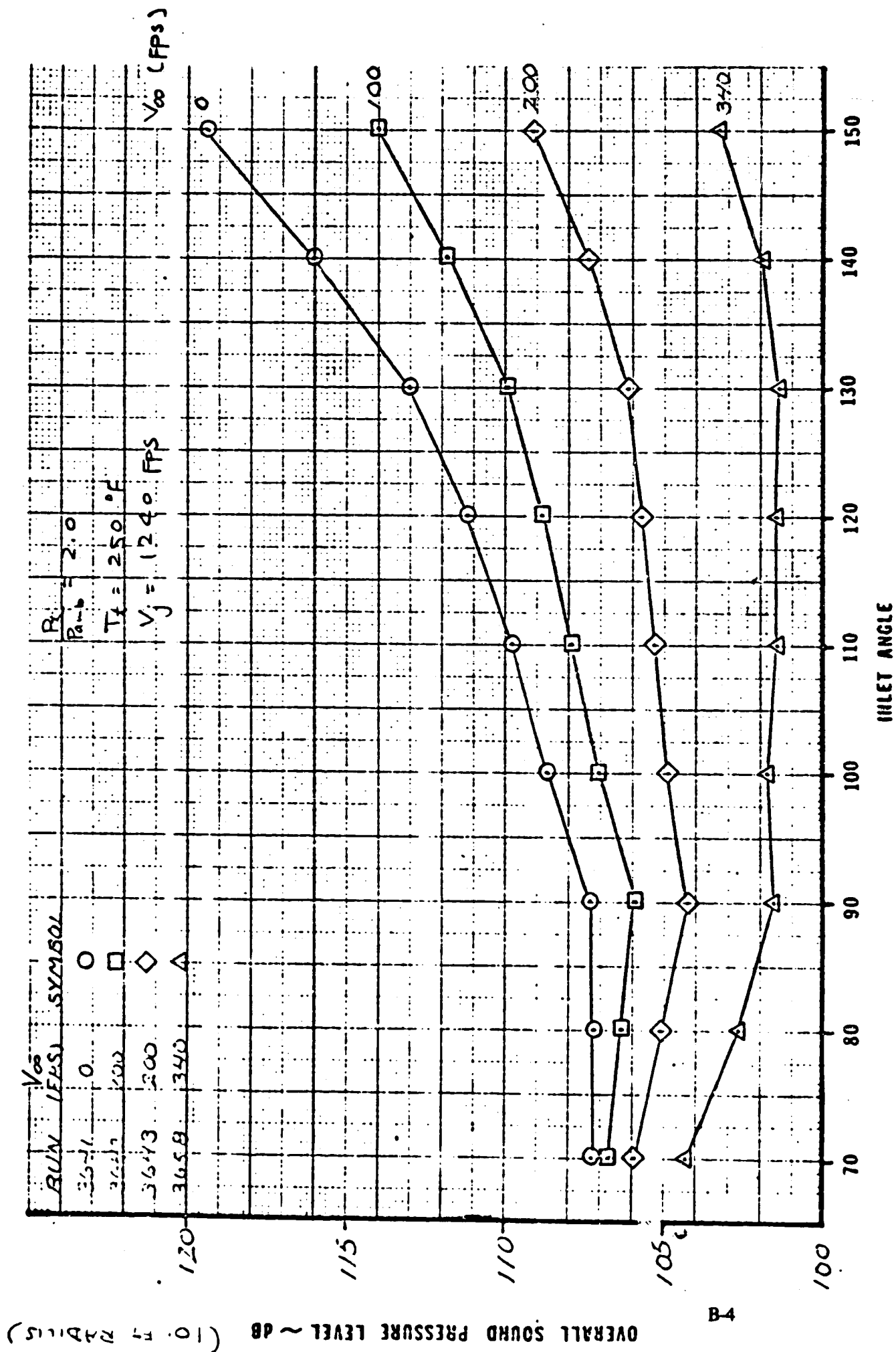
CONVERGENT NOZZLE

OVERALL SOUND PRESSURE LEVEL ~ DB (10 FT RADIUS)



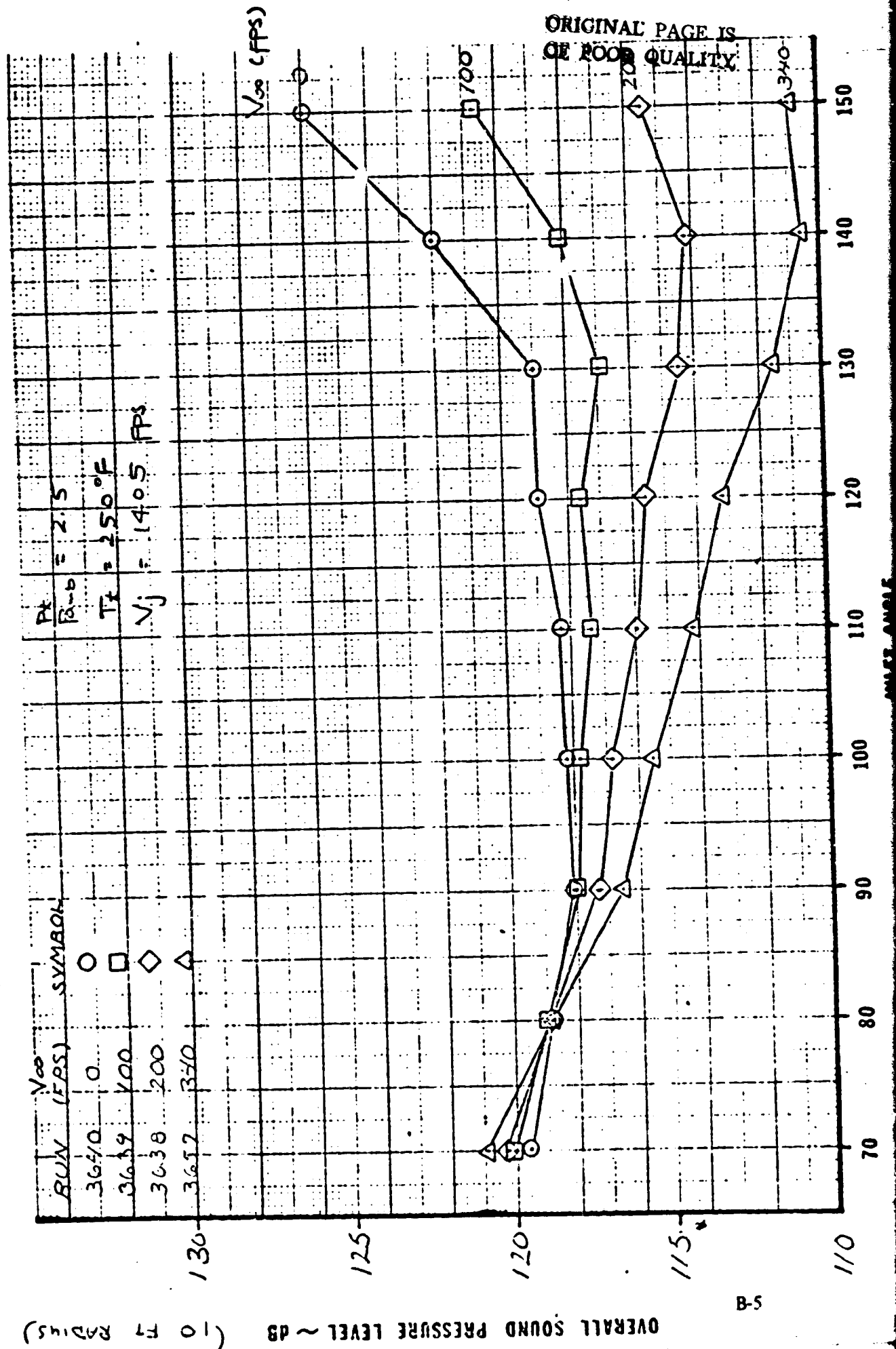
DIRECTIVITY

CONVERGENT NOZZLE



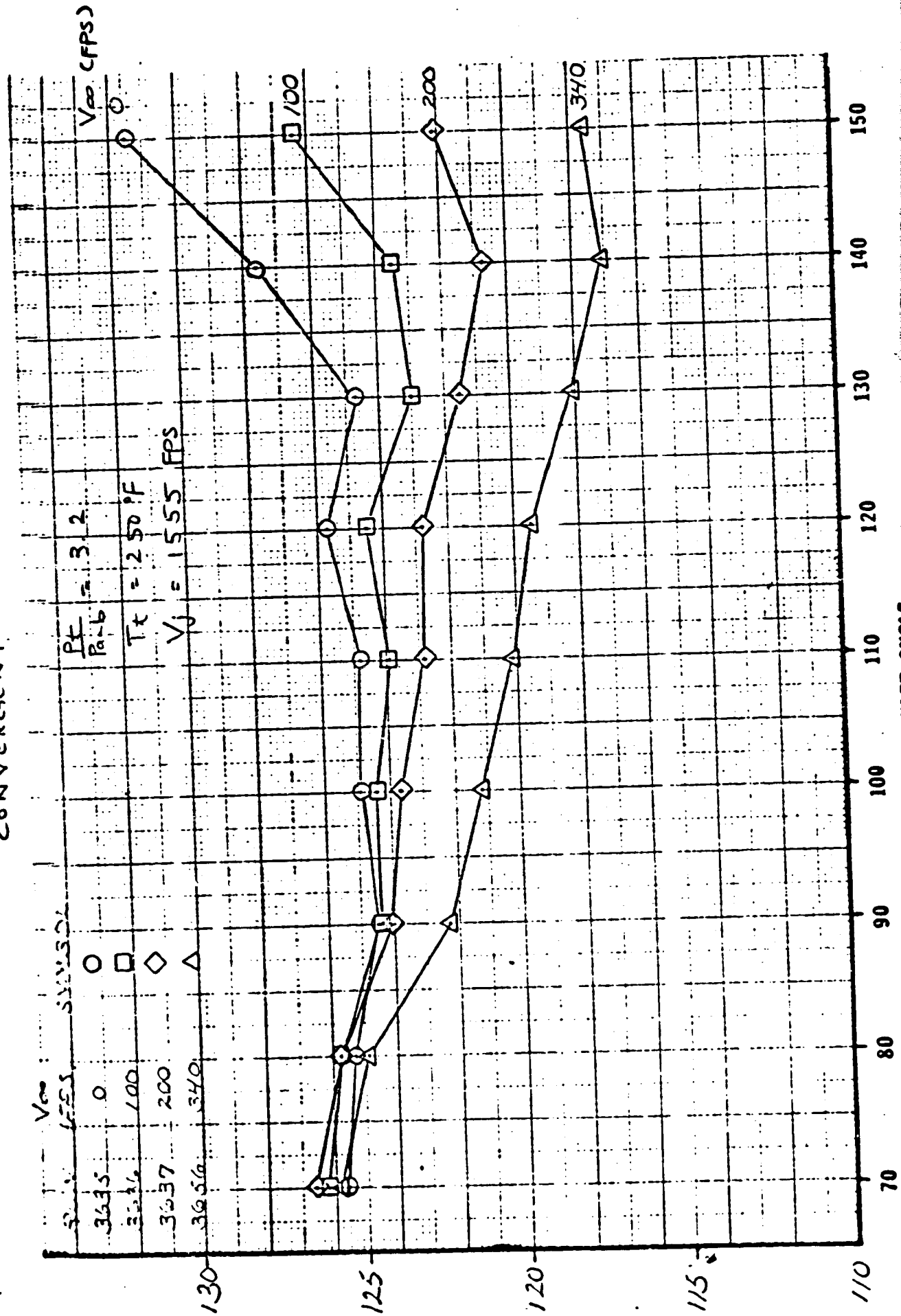
DIRECTIVITY

CONVERGENT NOZZLE



DIRECTIVITY

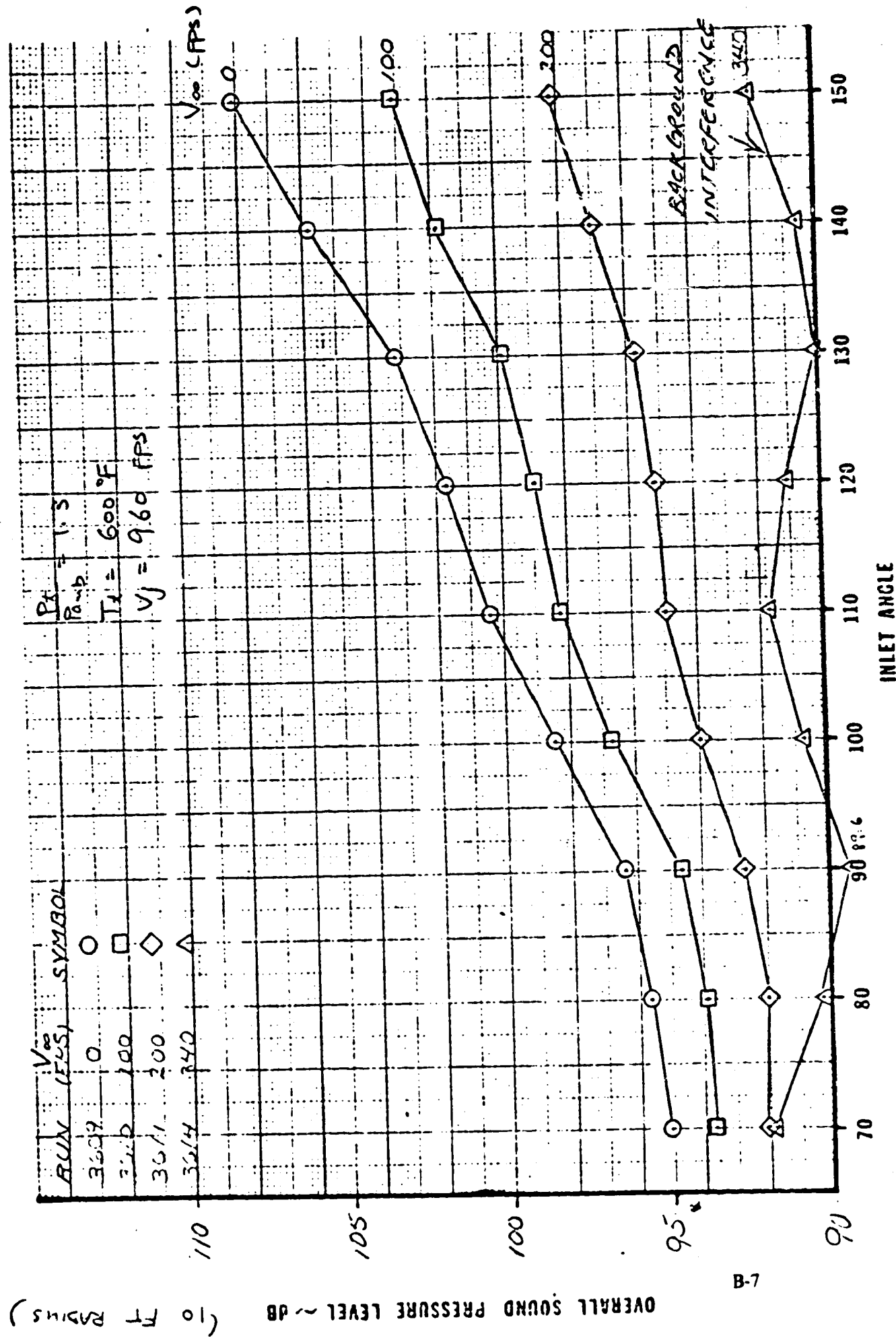
CONVERGENT NOZZLE



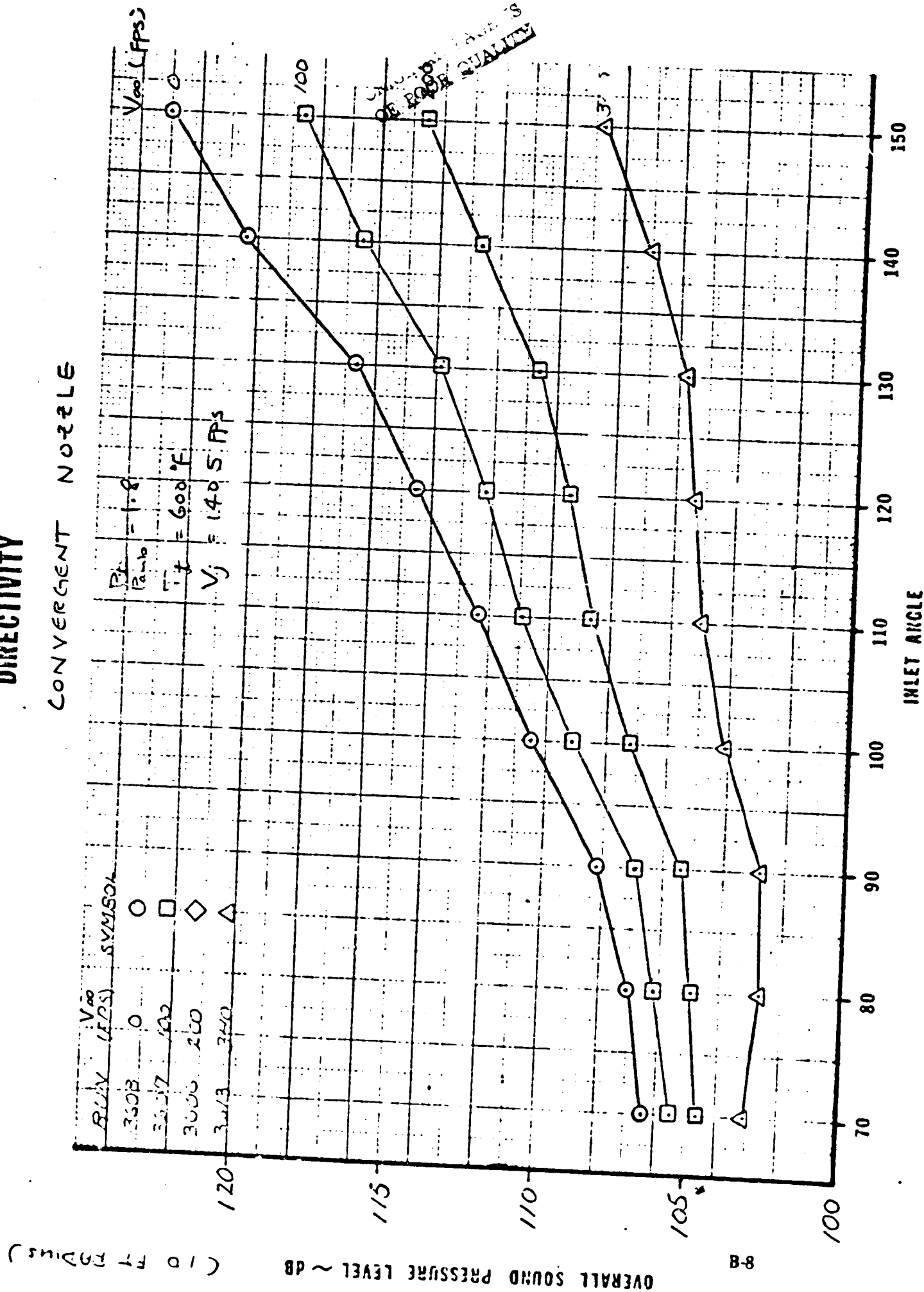
OVERALL SOUND PRESSURE LEVEL ~ dB (10 F 2000 Hz)

DIRECTIVITY

CONVERGENT NOZZLE



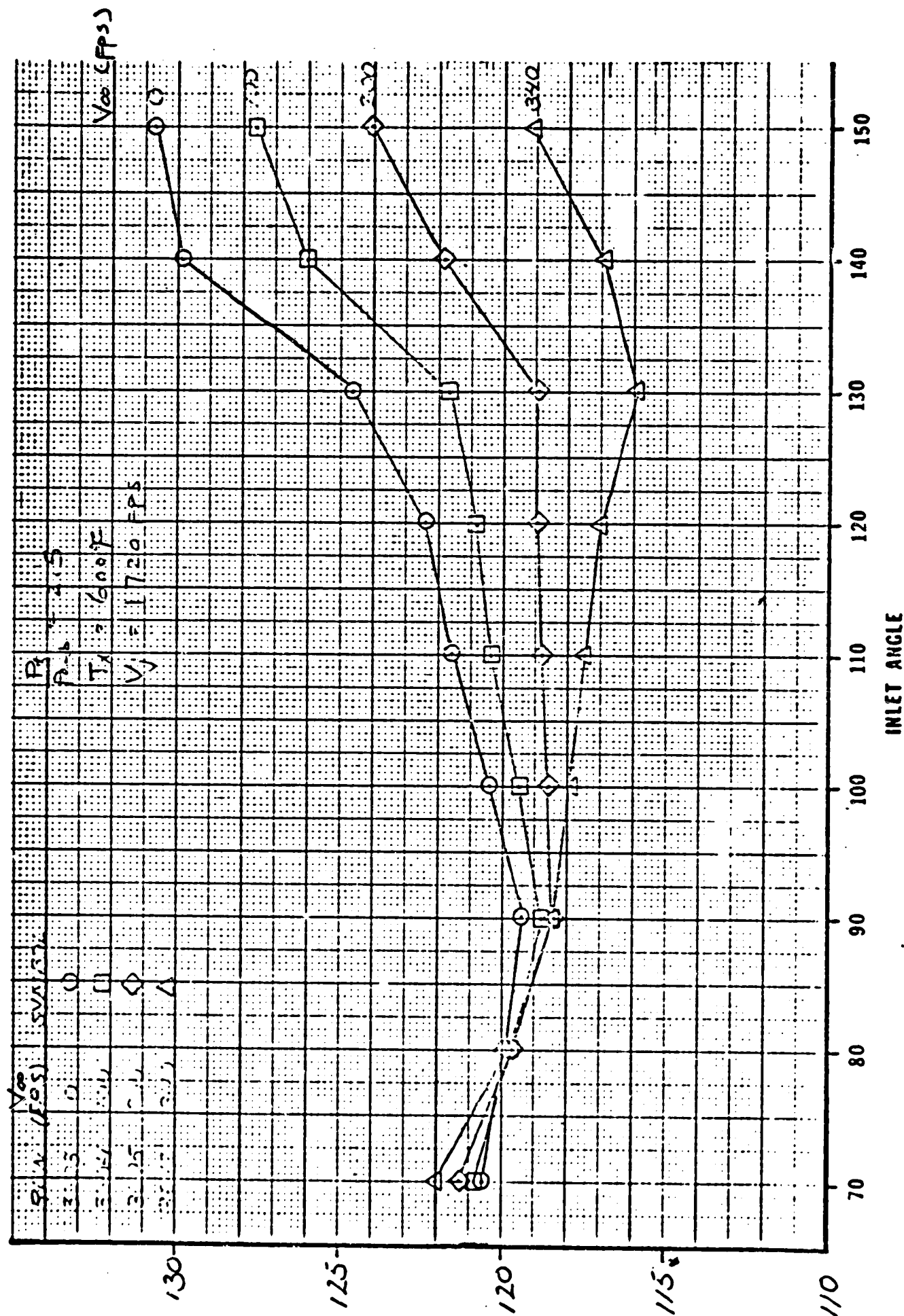
CONVERGENT NOZZLE



DIRECTIVITY

CONVERGENT NOZZLE

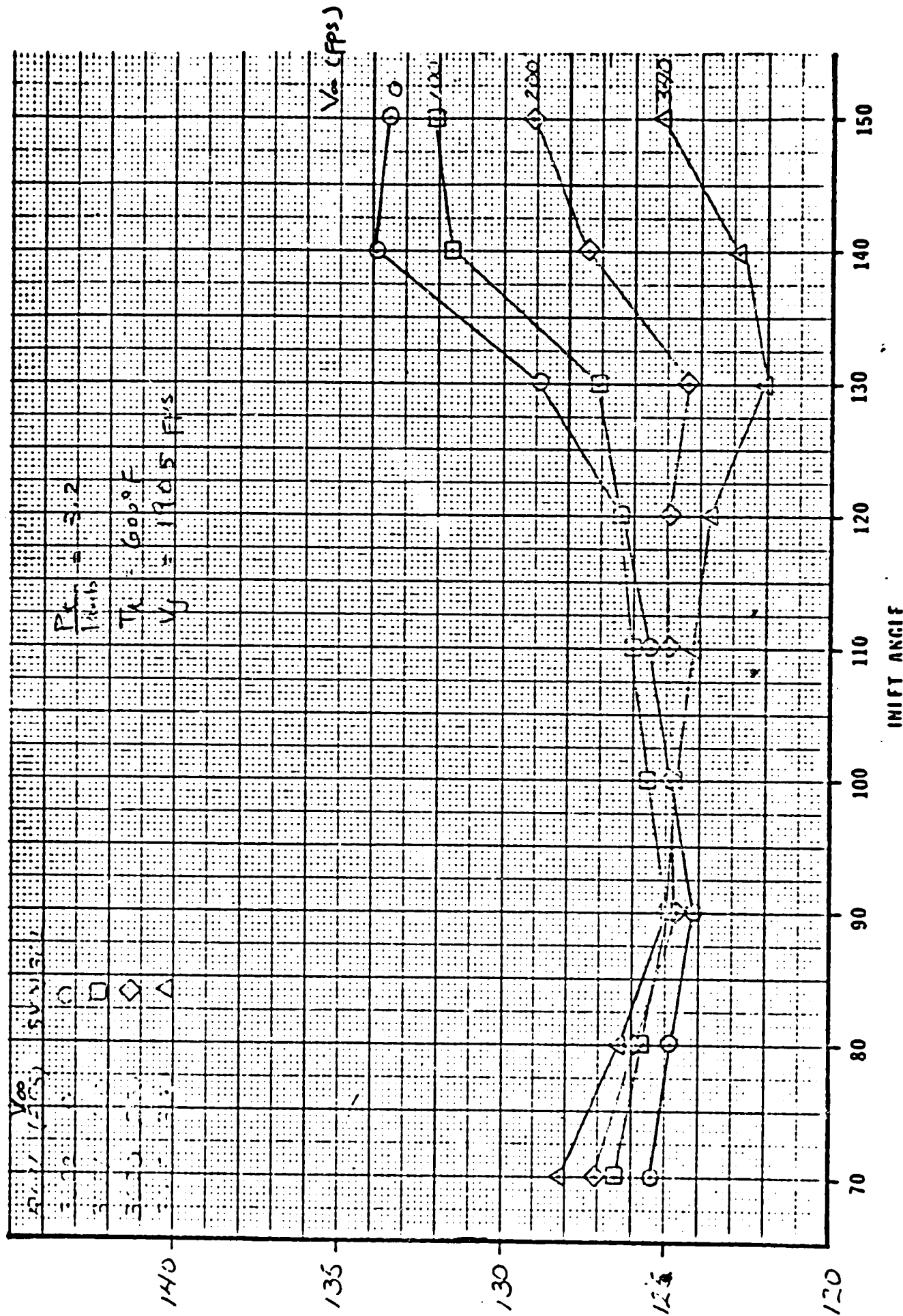
OVERALL SOUND PRESSURE LEVEL ~ 88 (10 FT radius)



DIRECTIVITY

CONVERGENT NOZZLE

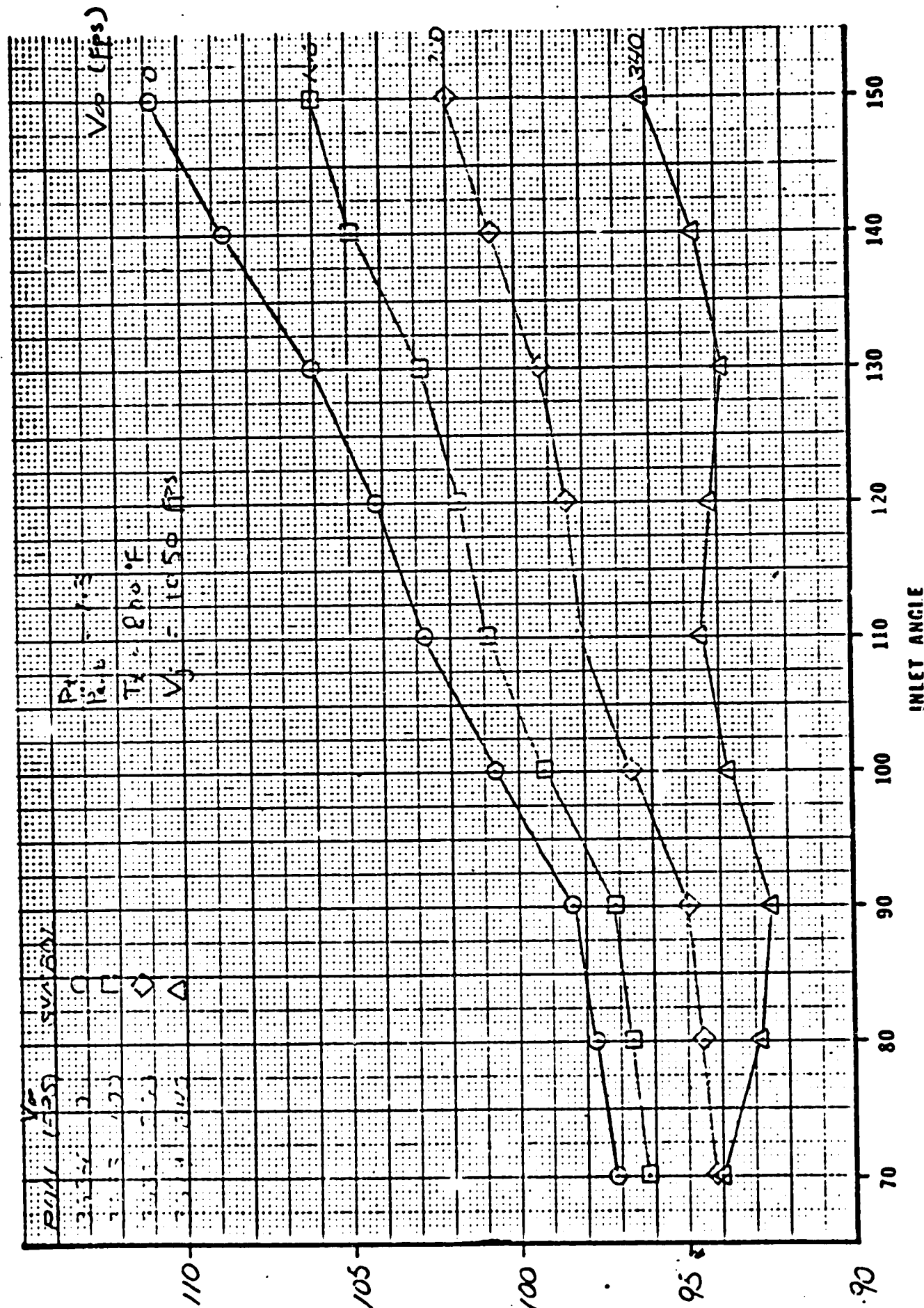
01-B OVERALL SOUND PRESSURE LEVEL ~ DB (10 FT Radius)



DIRECTIVITY

CONVERGENT NOZZLE

OVERALL SOUND PRESSURE LEVEL ~ 88 (10 FT RADII)

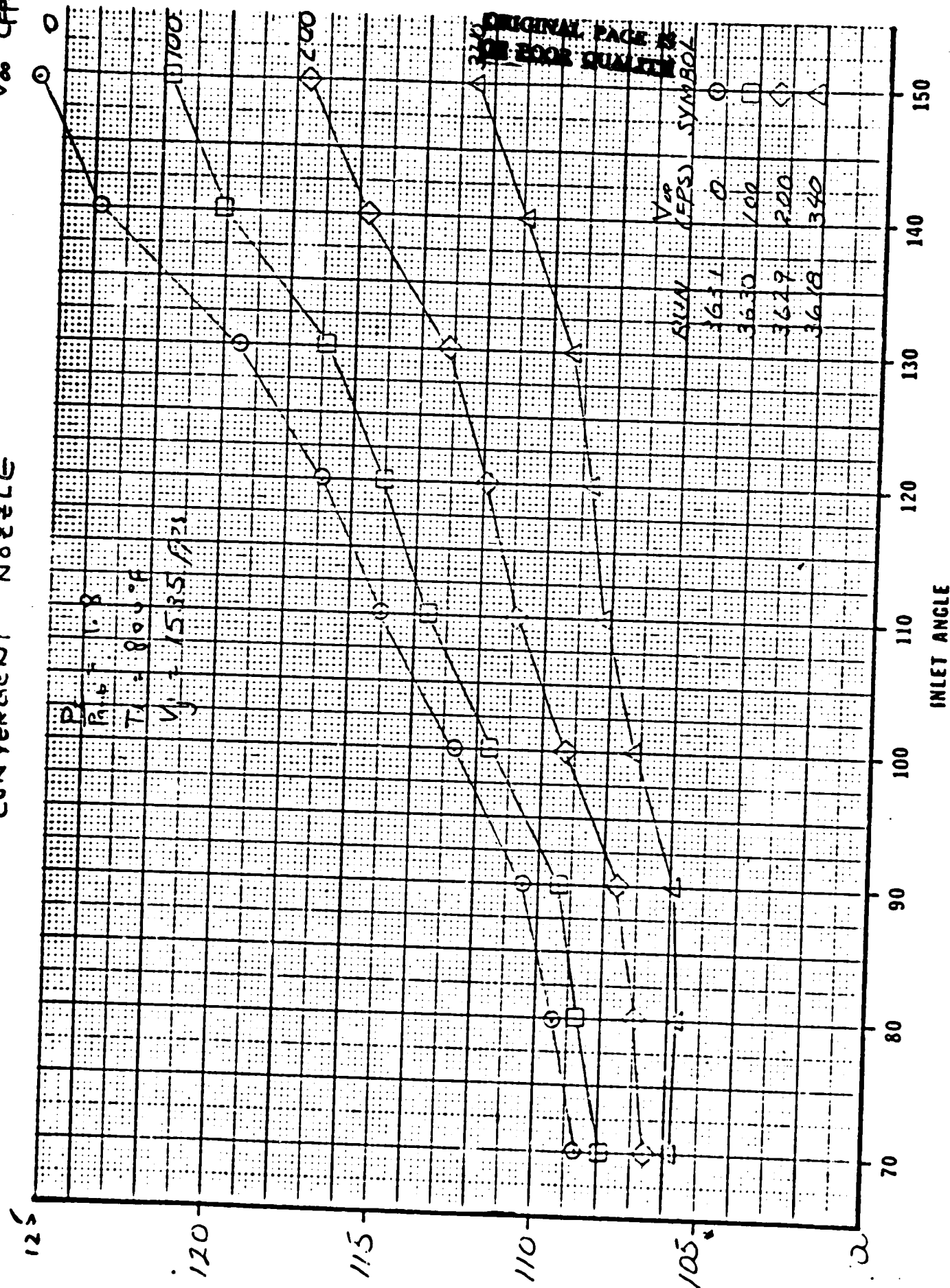


DIRECTIVITY

CONVERGENT NOZZLE

V_{∞} (FPS)

OVERALL SOUND PRESSURE LEVEL ~ dB (10 FT RADII)

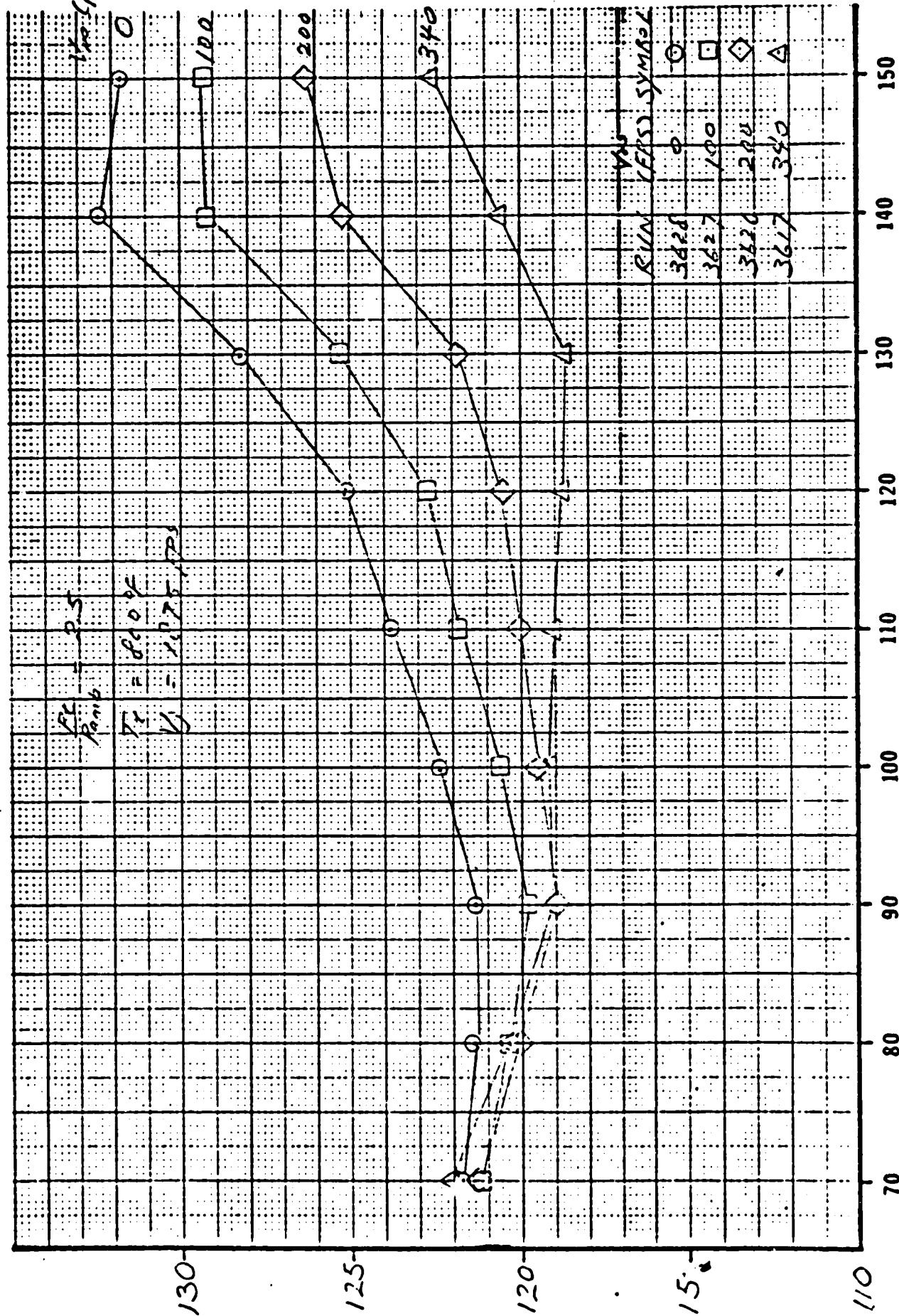


DIRECTIVITY

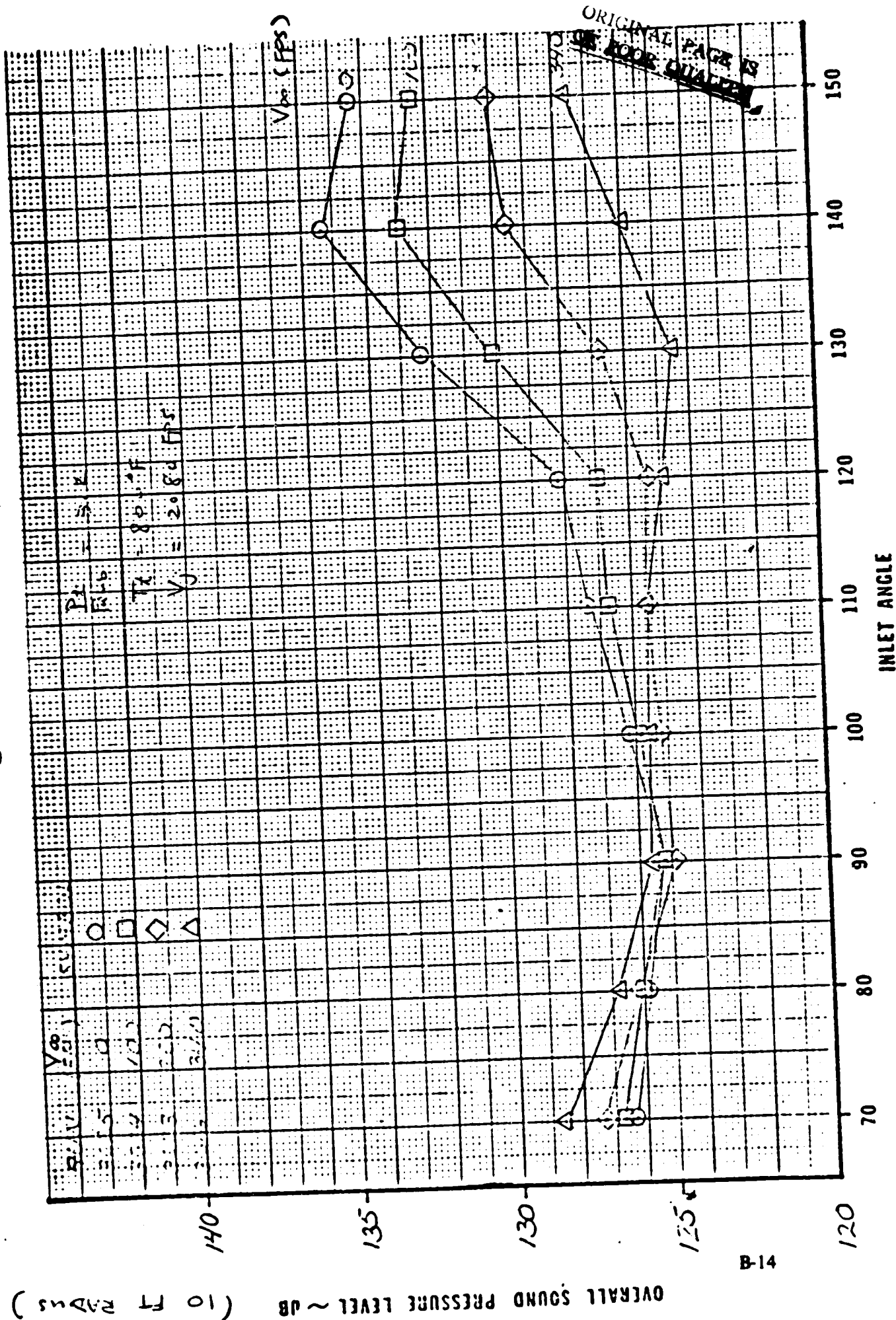
CONVERGENT NOZZLE

(10 FT RADIUS)

OVERALL SOUND PRESSURE LEVEL ~ DB



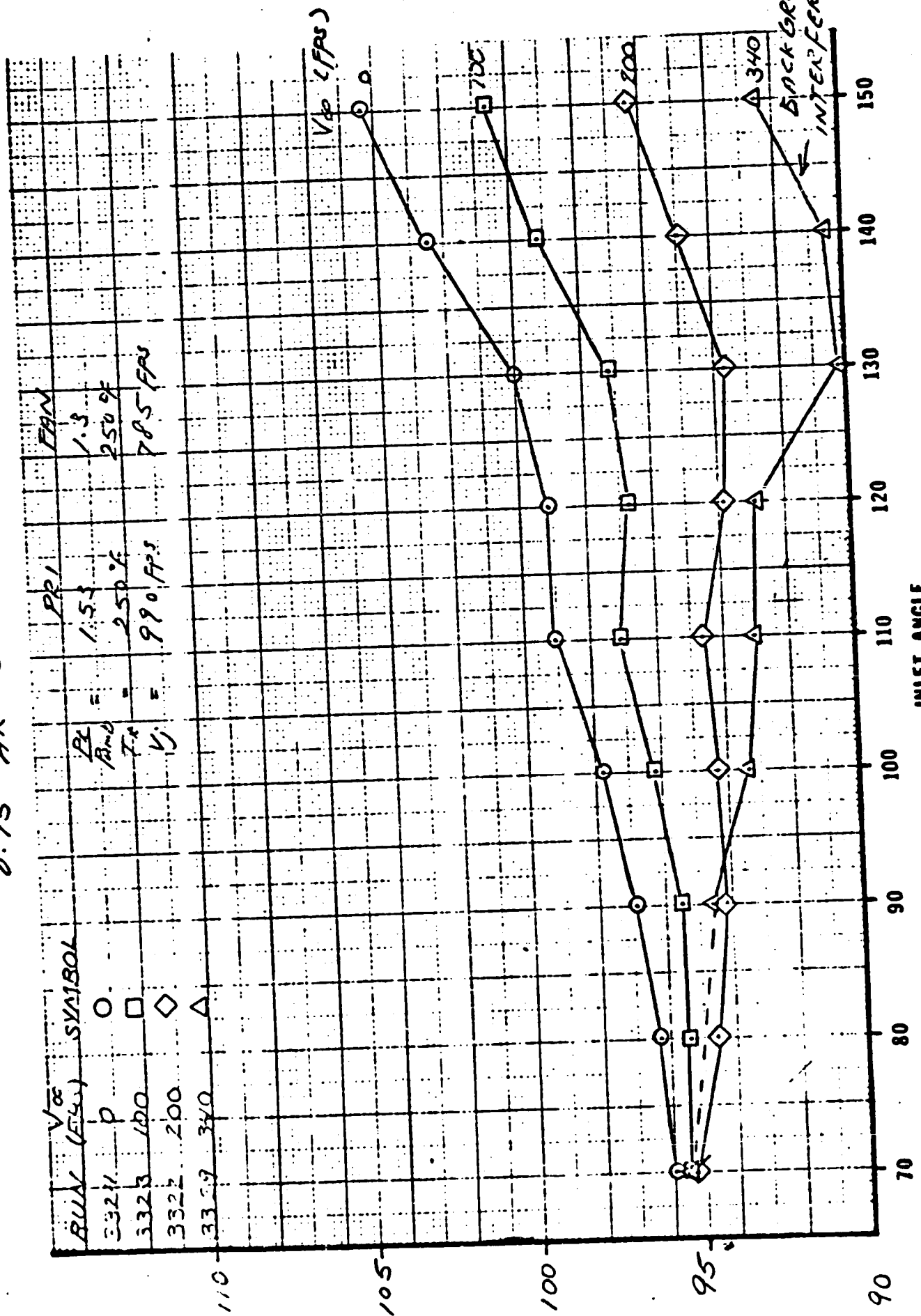
CONVERGENT NOZZLE



OVERALL SOUND PRESSURE LEVEL ~ 88 (10 FT RADIUS)

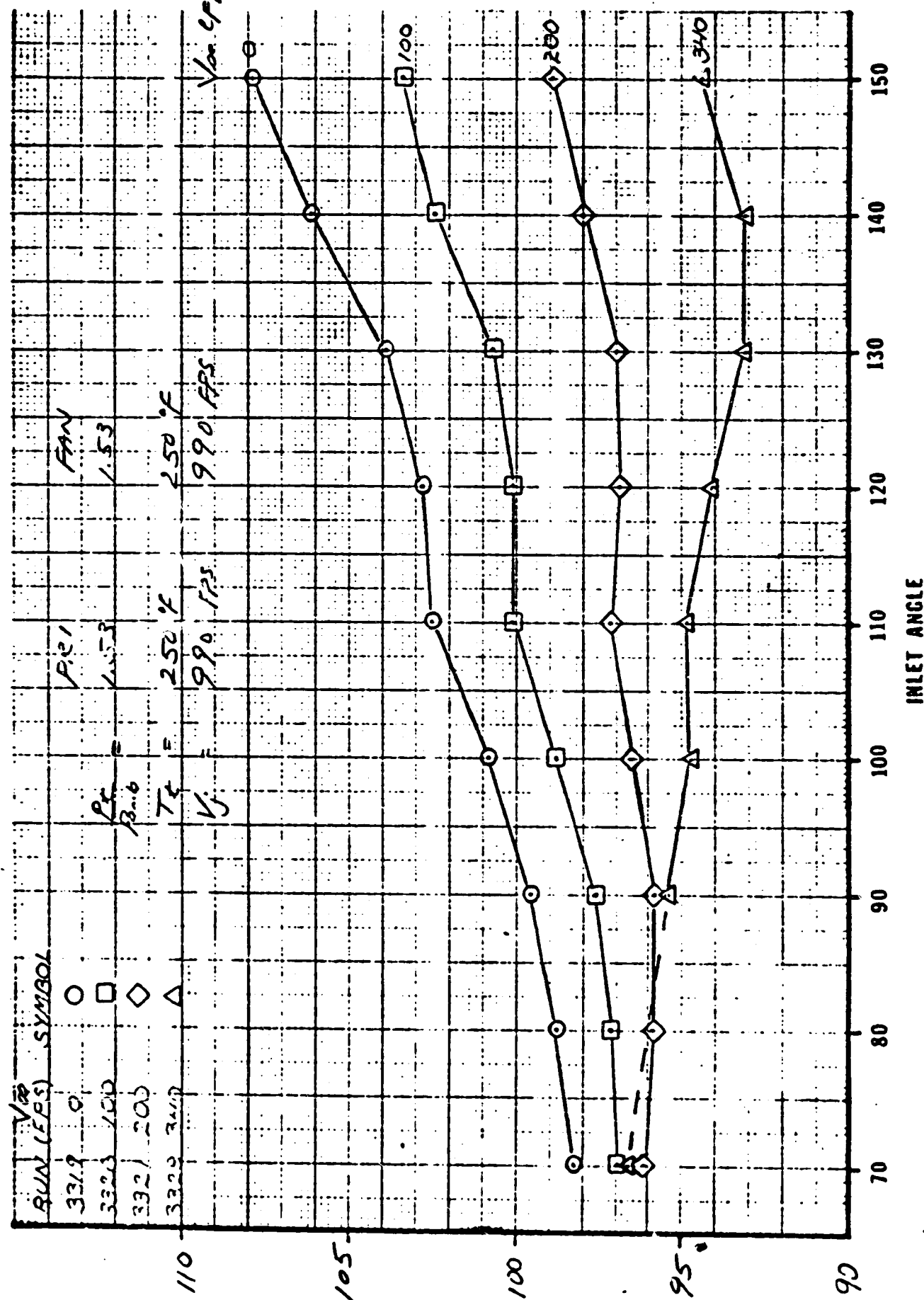
B-15

DIRECTIVITY 0.75 AR CONNULAR NOZZLE



DIRECTIVITY

0.75 AR CONNULAR NOZZLE

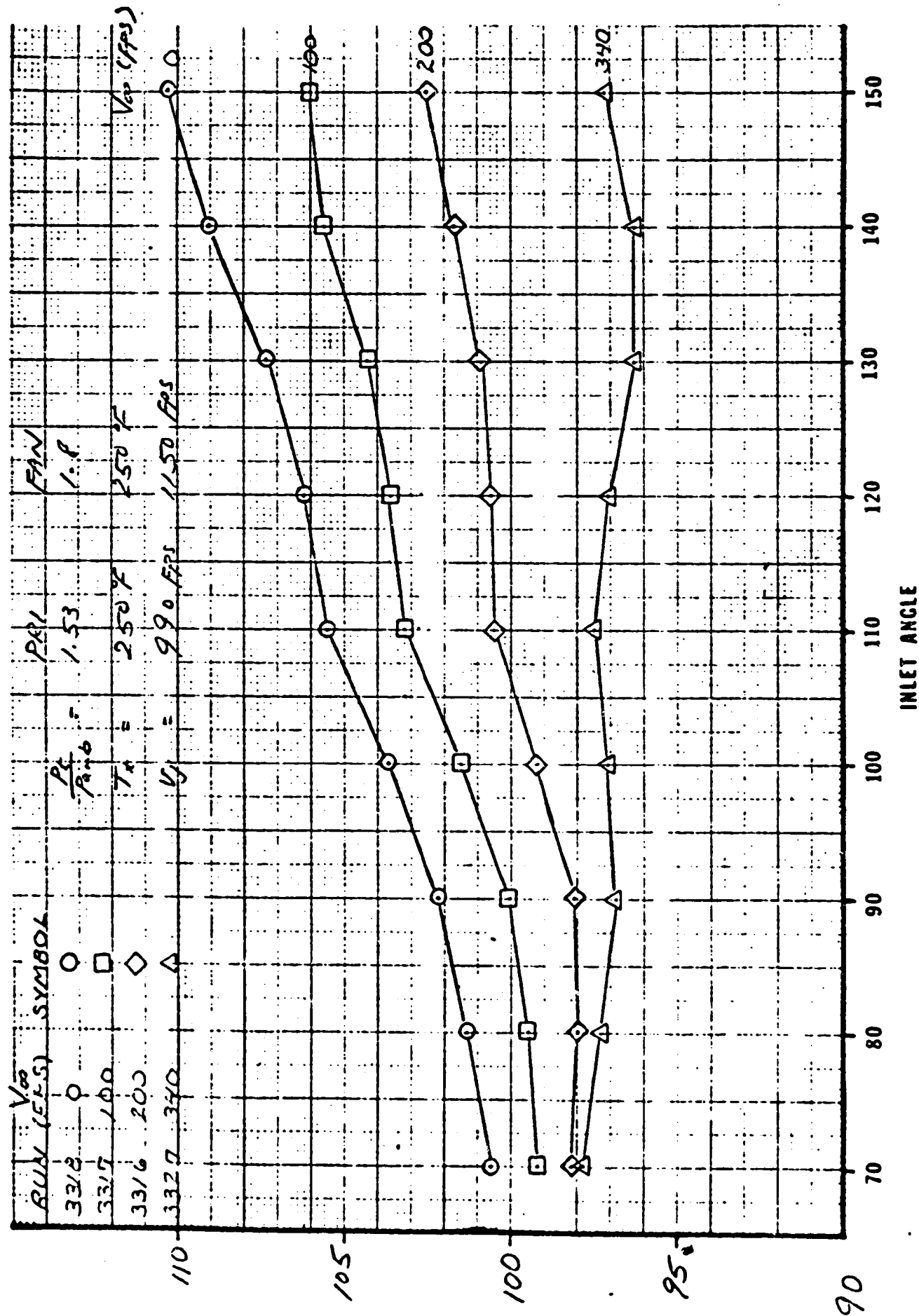


OVERALL SOUND PRESSURE LEVEL ~ dB (10 FT RADII)

DIRECTIVITY

0.75 AR CONNULAR NOZZLE

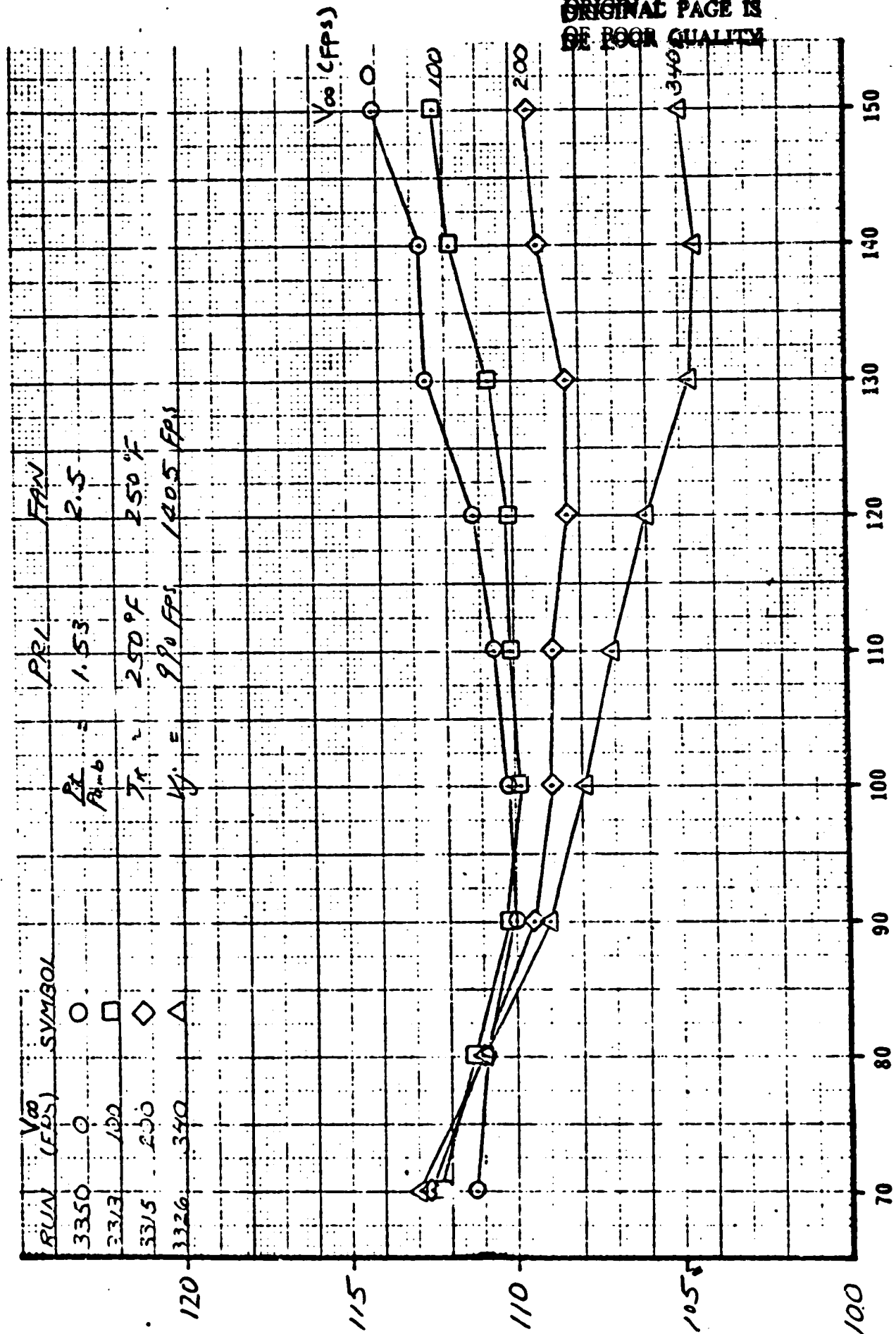
(10 FT RADIUS)



DIRECTIVITY

0.75 AR CONNULAR NOZZLE

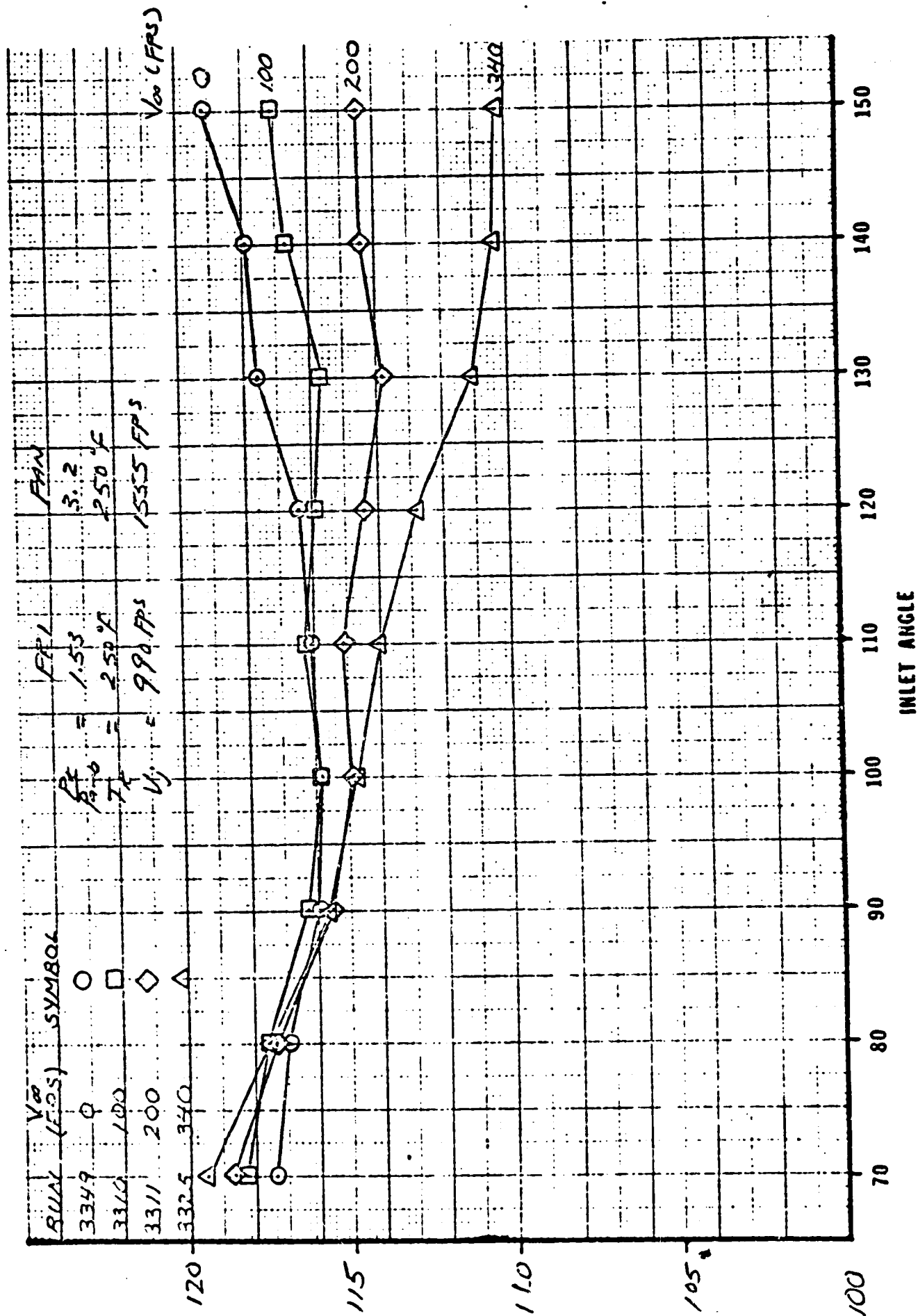
OVERALL SOUND PRESSURE LEVEL ~ 80 DB (10 FT RADIUS)



DIRECTIVITY

0.75 AR CONNULAR NOZZLE

(10 FT Radius)



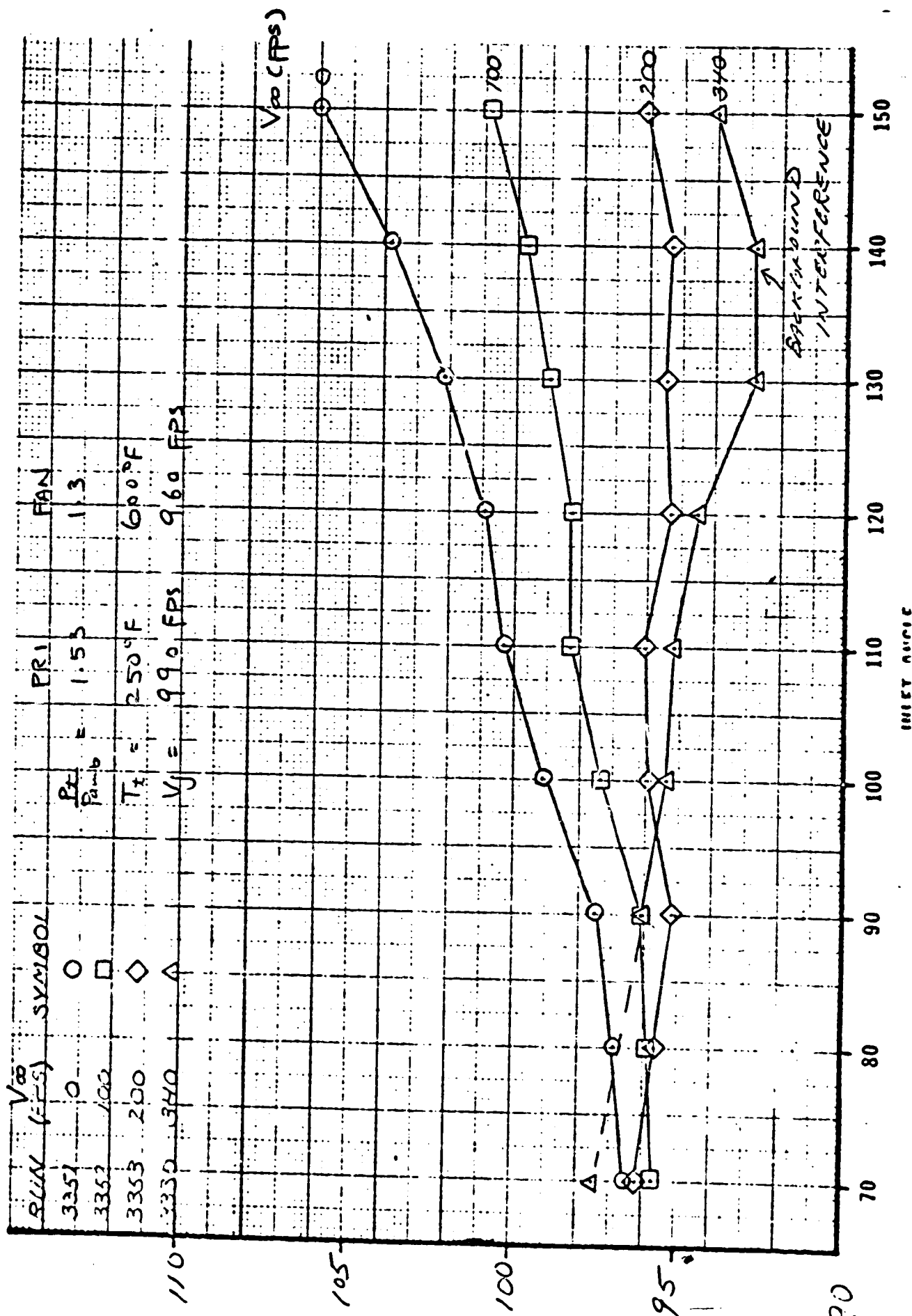
DIRECTIVITY

0.75 AR CONNULAR NOZZLE

(10 FT RADIUS)

OVERALL SOUND PRESSURE LEVEL ~ DB

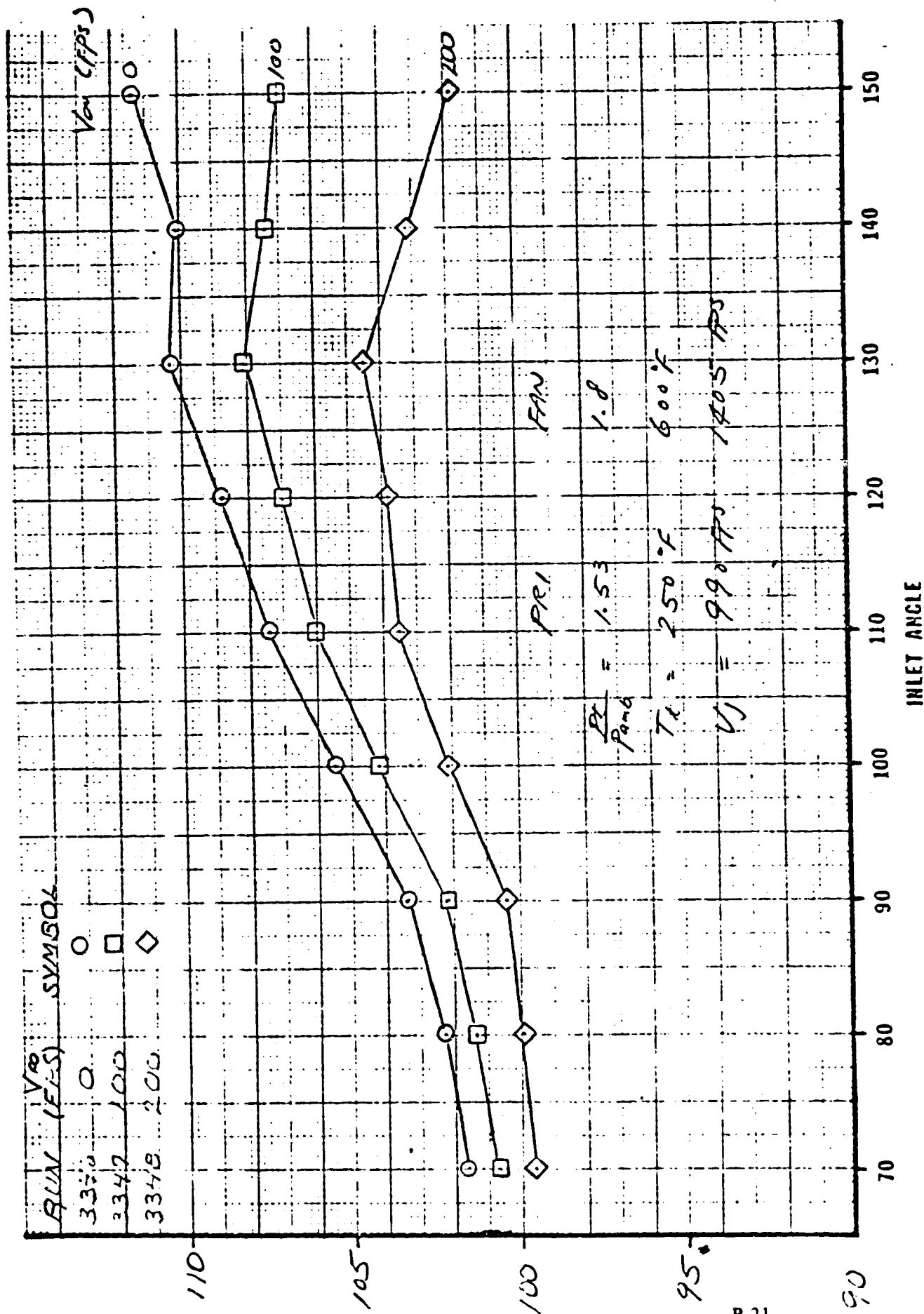
B-20



DIRECTIVITY

0.75 AR CONNULAR NOZZLE

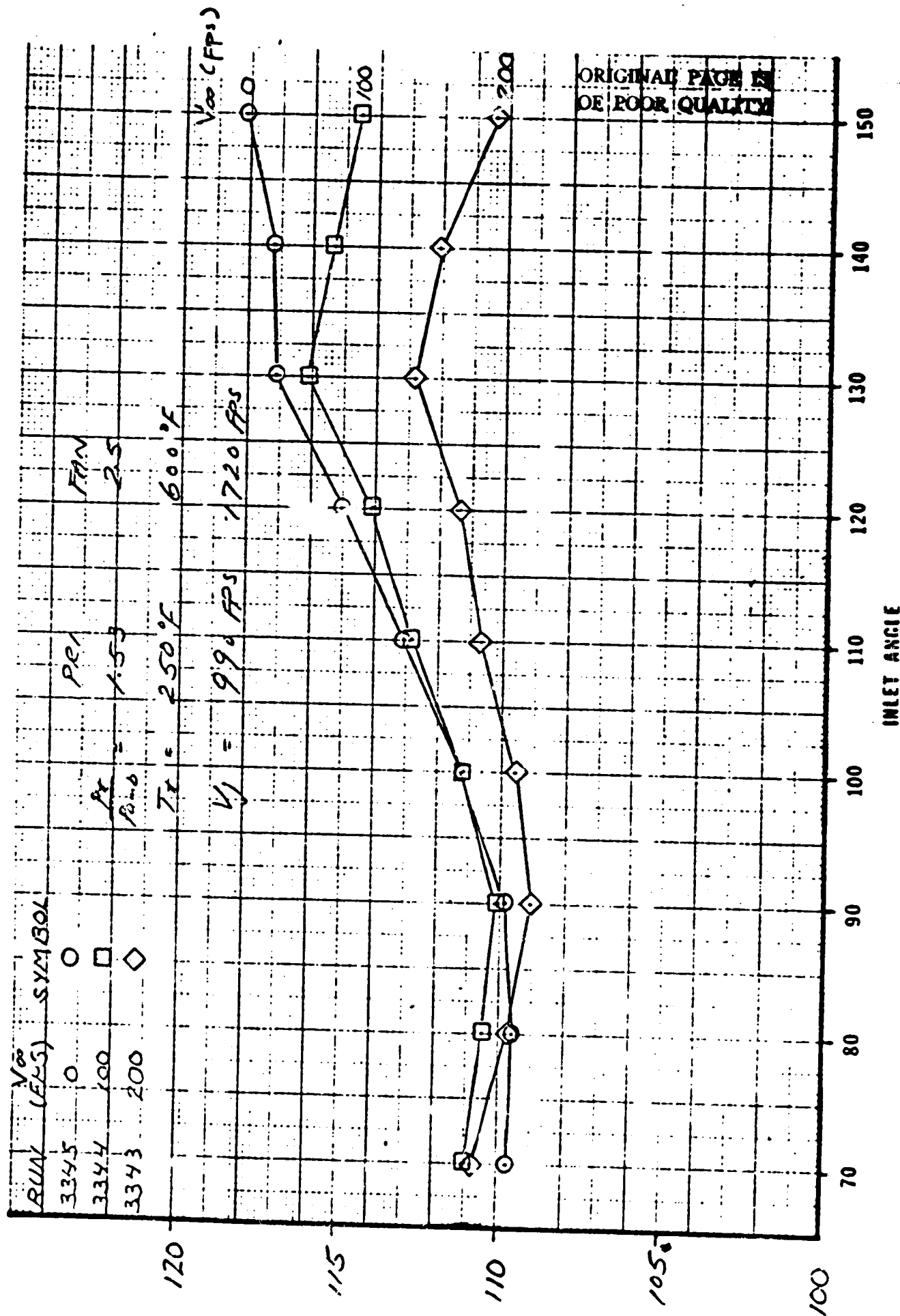
OVERALL SOUND PRESSURE LEVEL ~ DB (10 FT RADII)



DIRECTIVITY

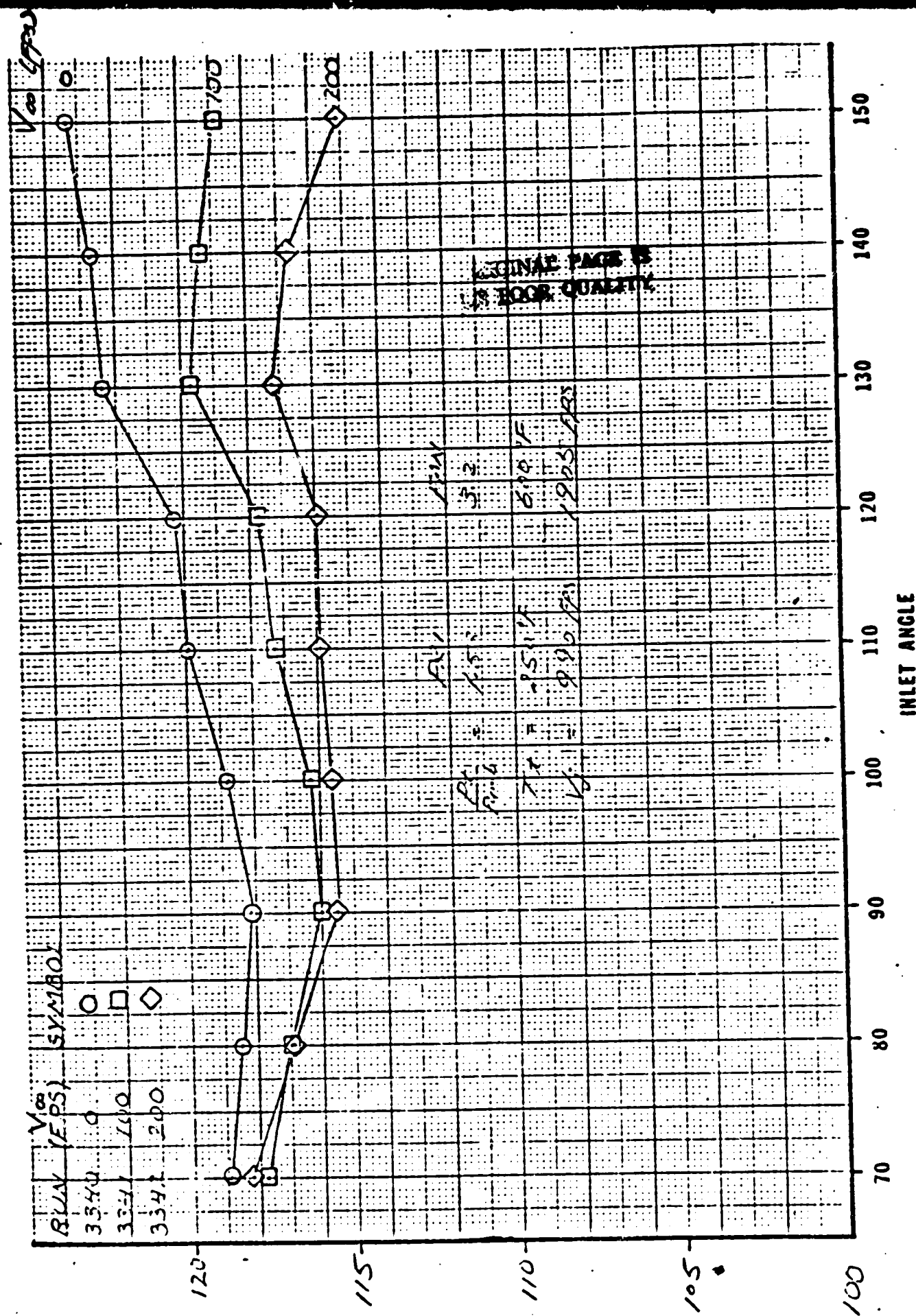
0.75 AIR COANNULAR NOZZLE

(10 FT Radius)



OVERALL SOUND PRESSURE LEVEL ~ DB

0.75 AR CORRUGULAR, NOZZLE



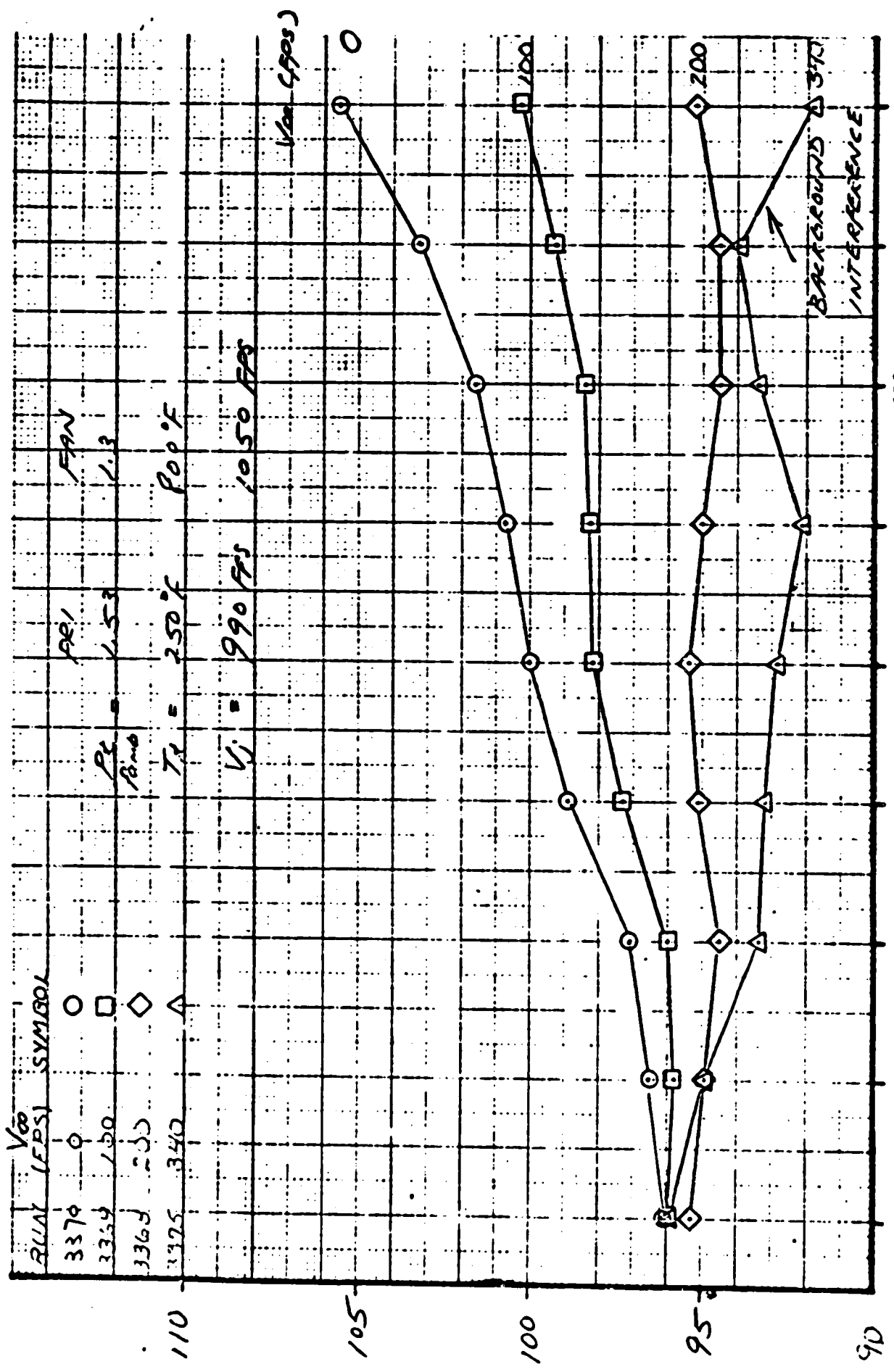
OVERALL SOUND PRESSURE LEVEL ~ 88 (10 m Radius)

B-23

DIRECTIVITY

0.75 AR CONNULAR NOZZLE

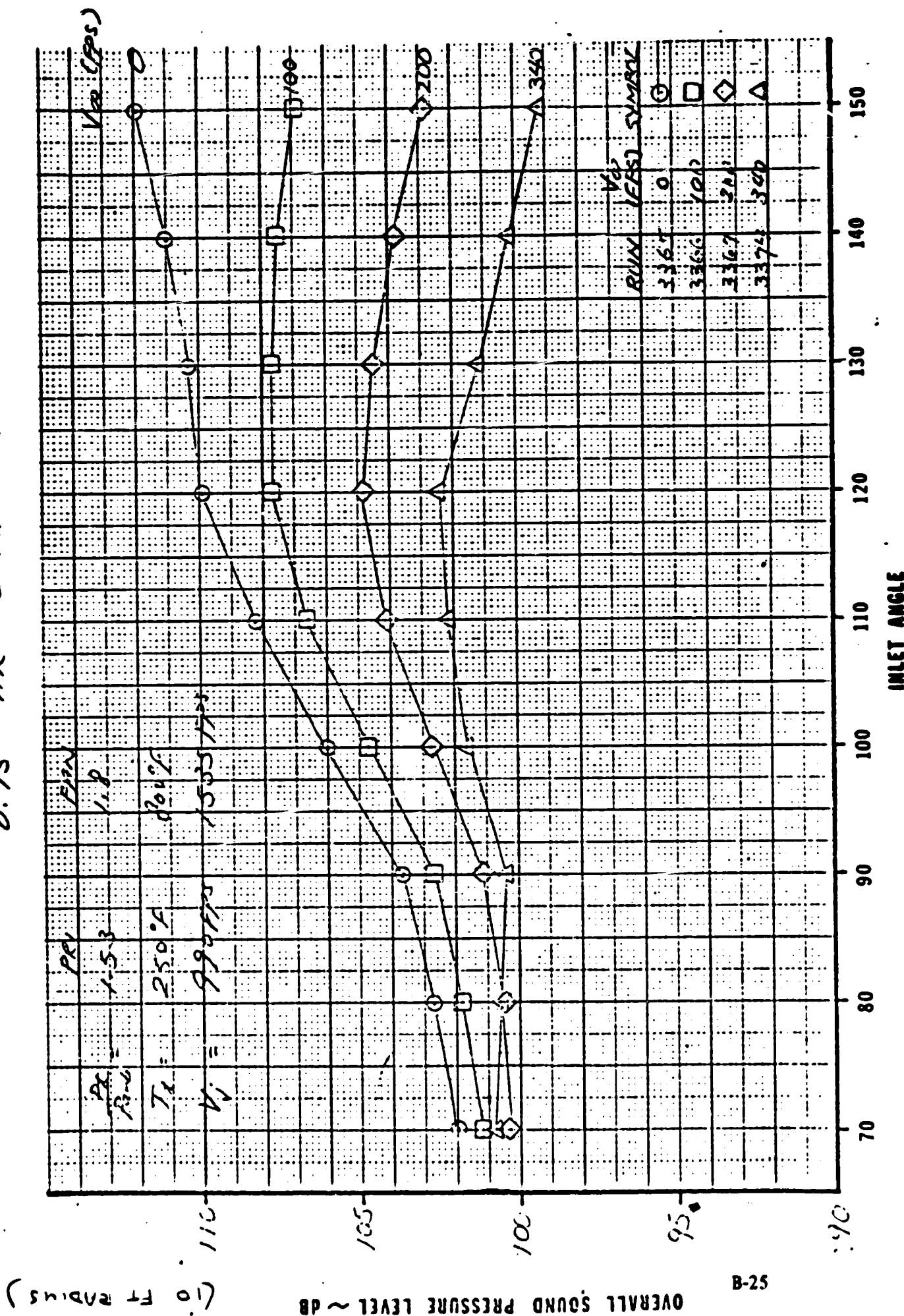
(10 FT RADII)



OVERALL SOUND PRESSURE LEVEL ~ dB

DIRECTIVITY

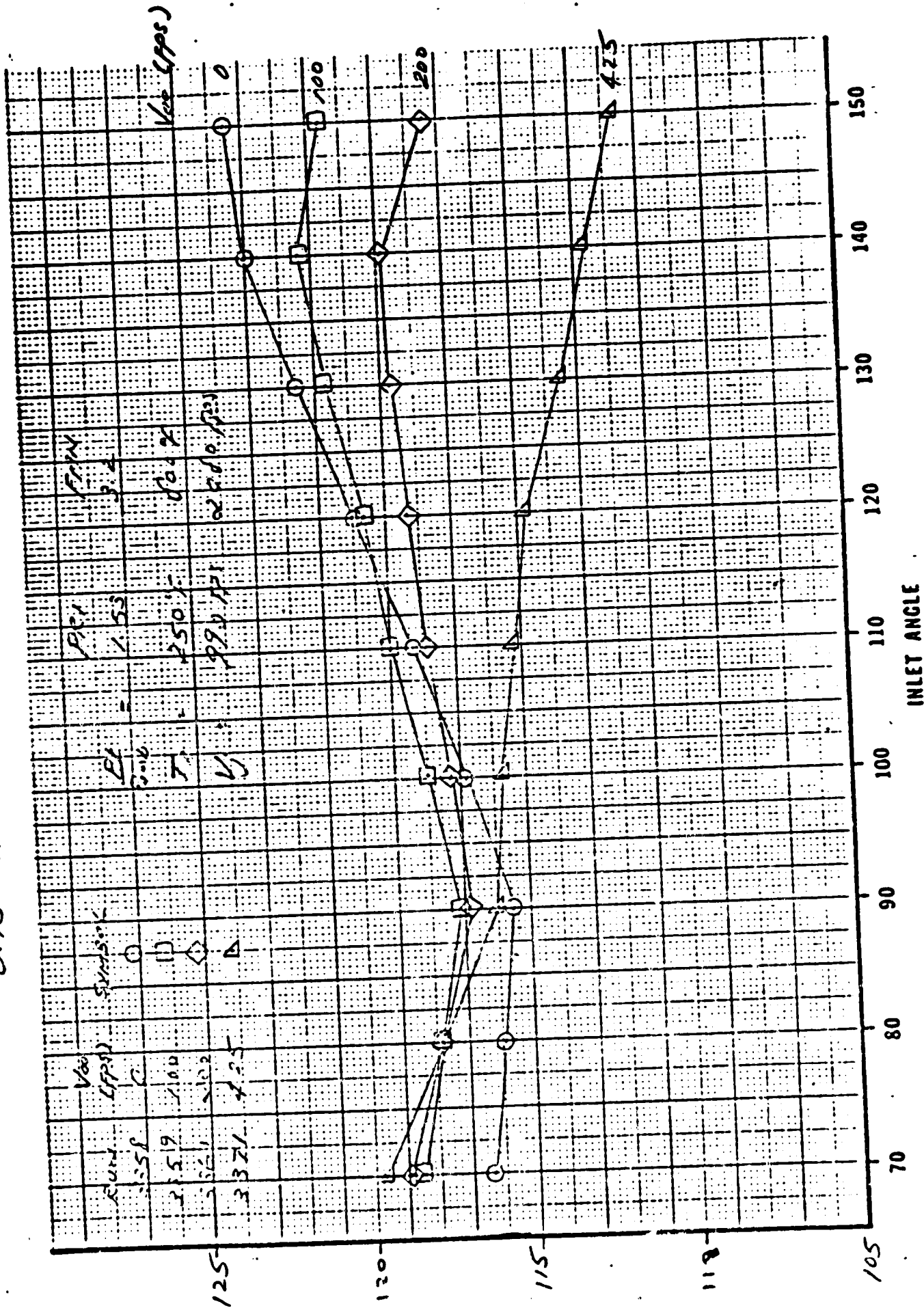
0.75 AR CANNULAR NOZZLE



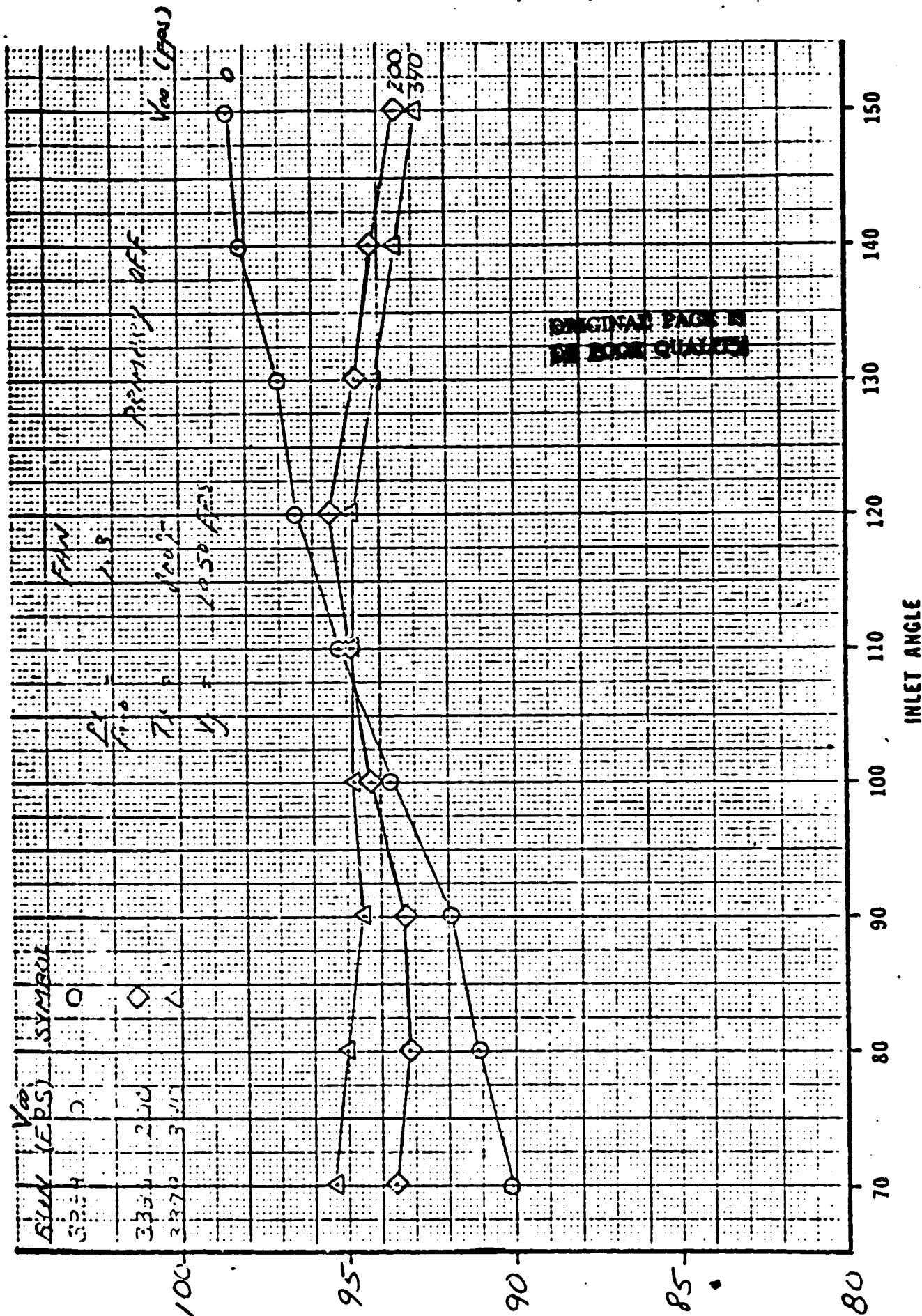
DIRECTIVITY

0.75 AR CONICAL NOZZLE

OVERALL SOUND PRESSURE LEVEL ~ 48 (10 ft radius)



DIRECTIVITY
0.75 AC COMMUNAR NO2226



(10 FT RADIIUS)

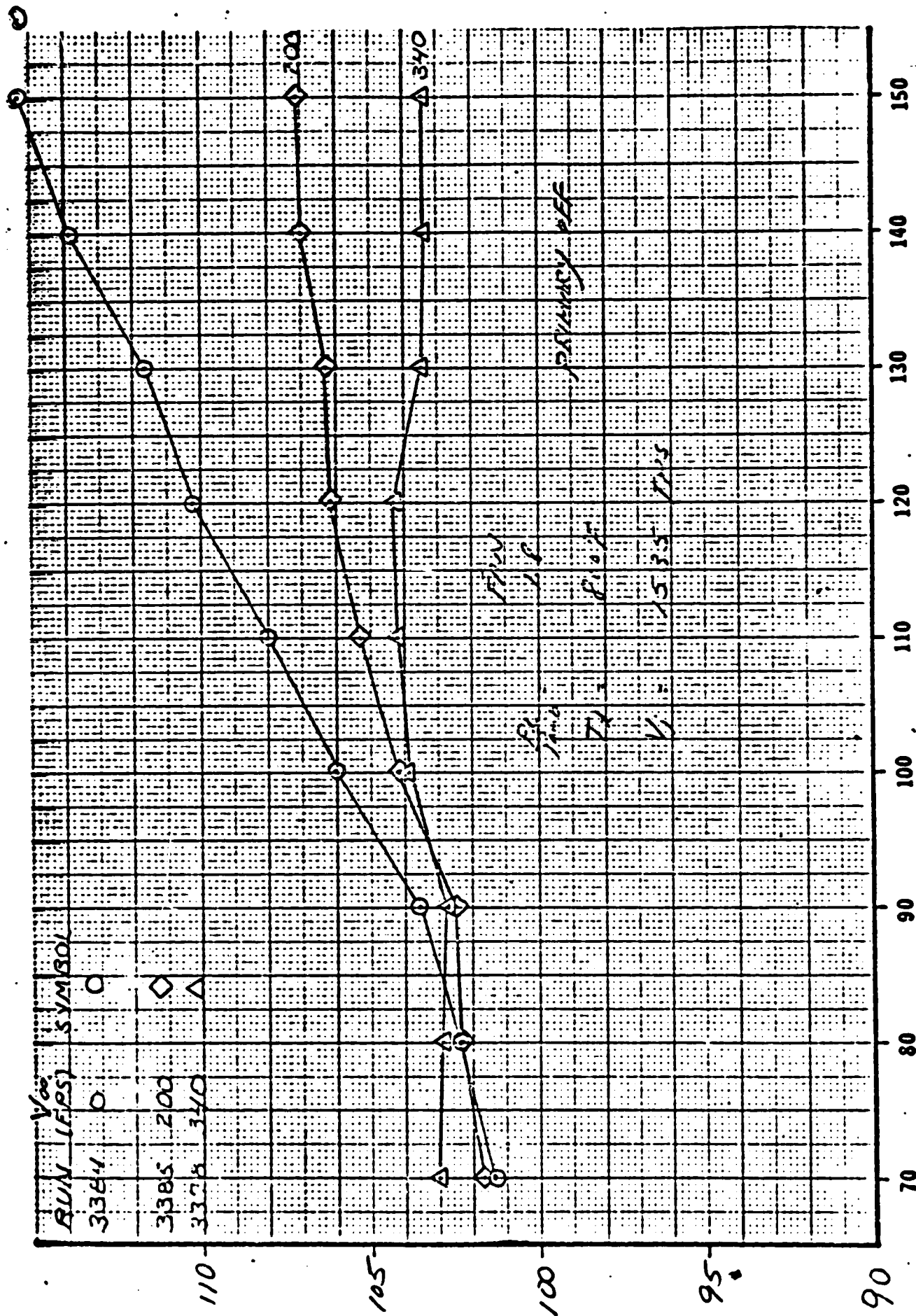
OVERALL SOUND PRESSURE LEVEL ~ dB

B-29

DIRECTIVITY

0.75 AR CONNUNDR NOZZLE

V_∞ (FPS)



(10 FT RADII)

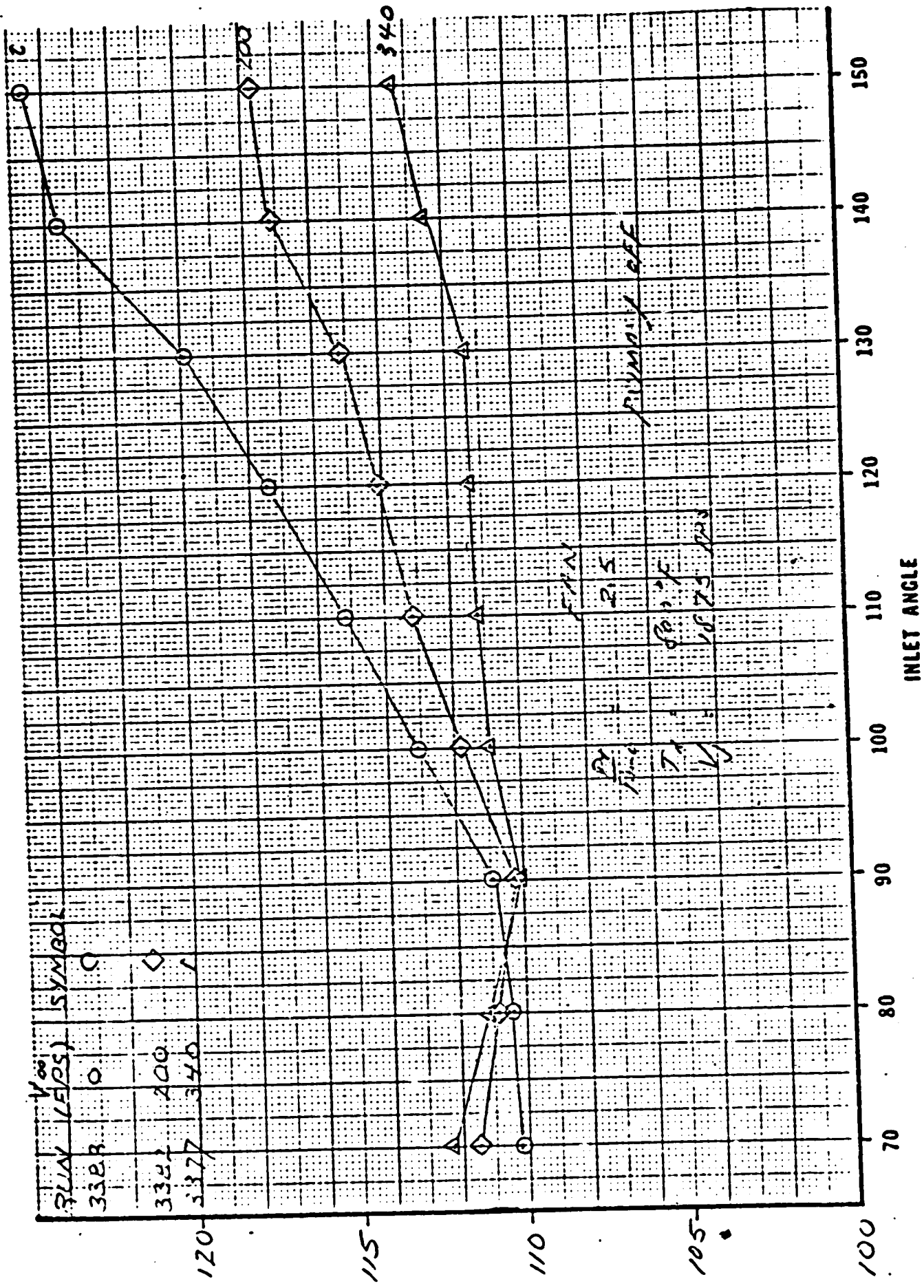
OVERALL SOUND PRESSURE LEVEL ~ DB

B-30

DIRECTIVITY

0.75 AR CONNULAR NOZZLE

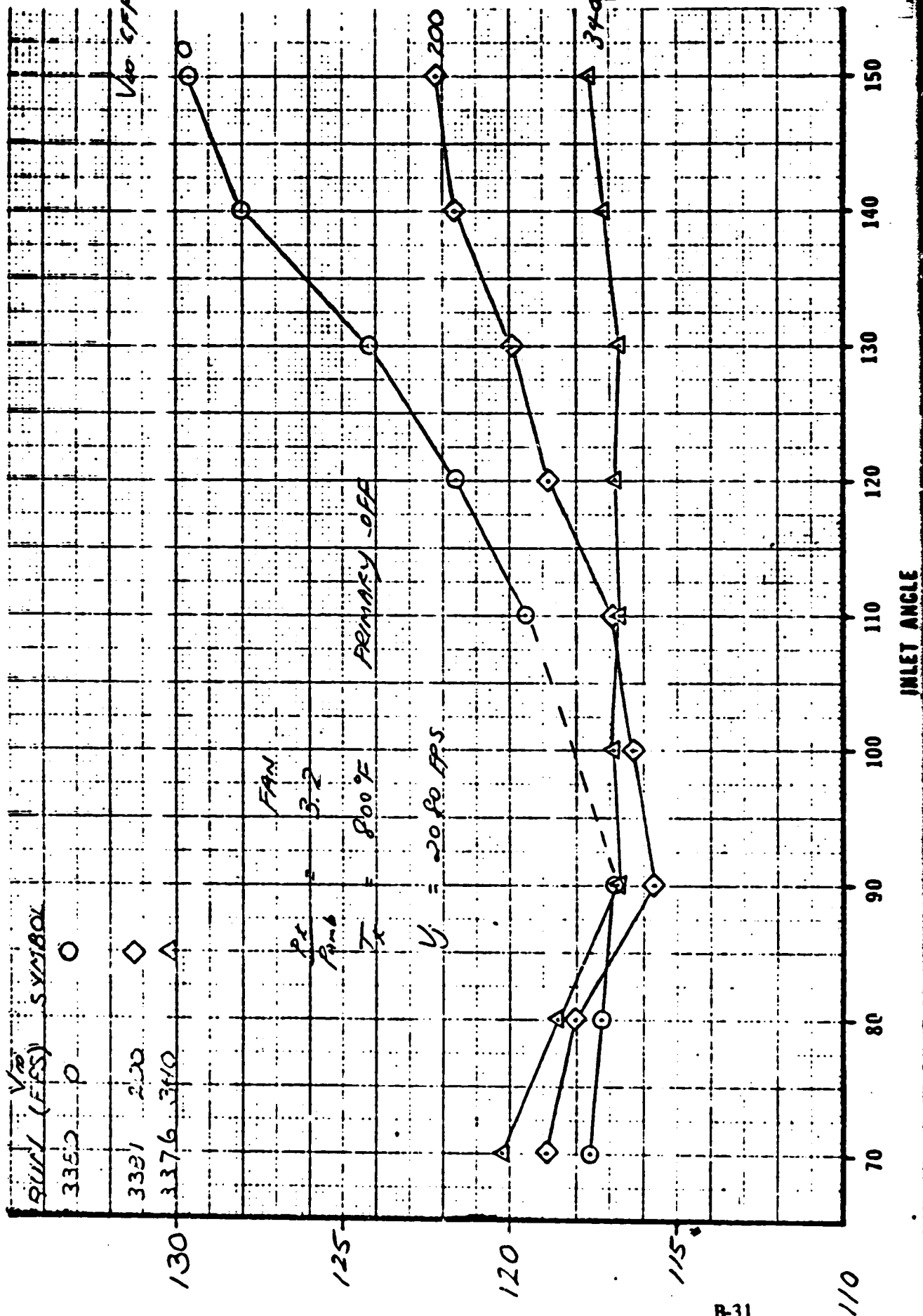
V_{∞} (FPS)



DIRECTIVITY

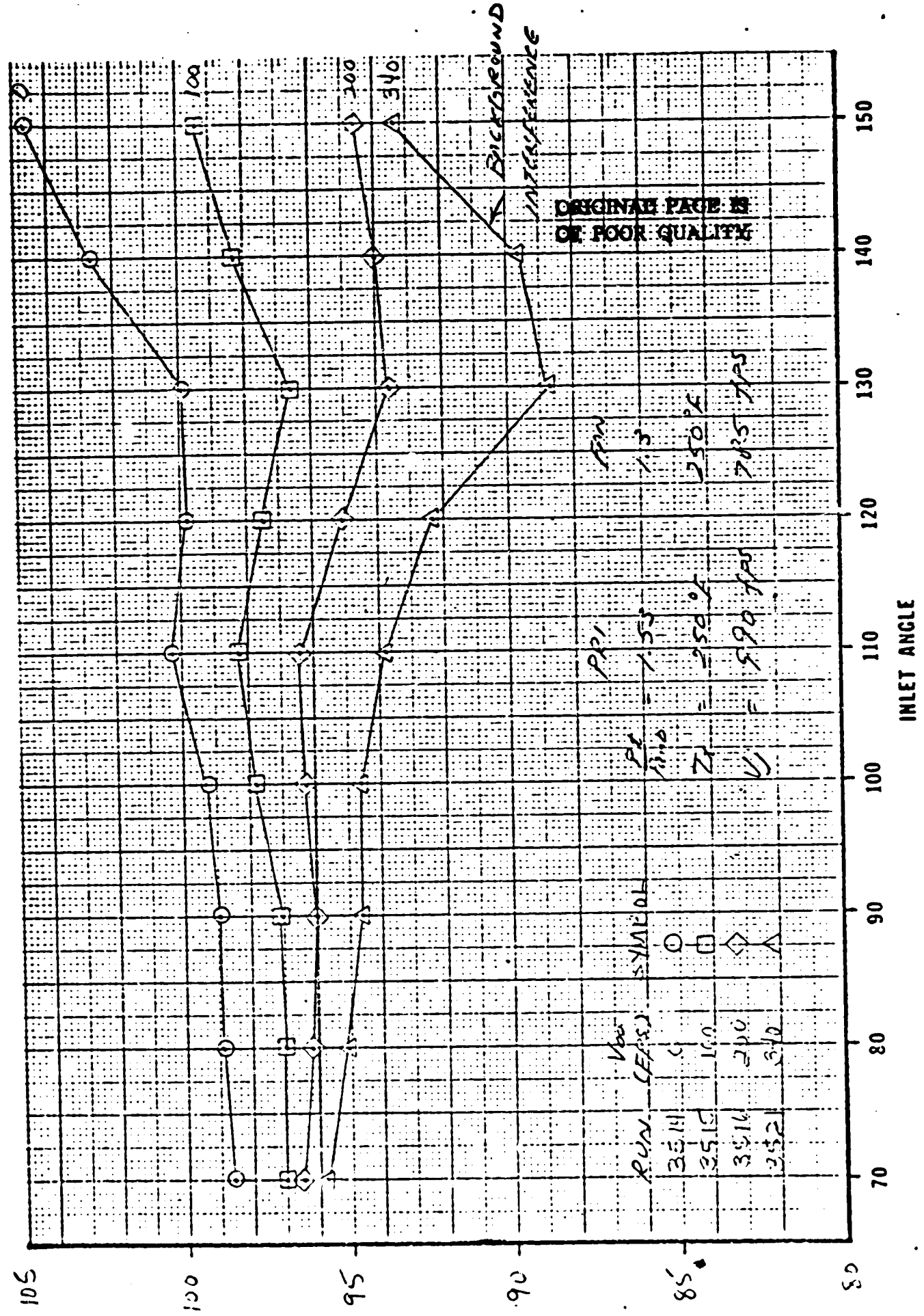
0.75 AR CONNULAR NOZZLE

OVERALL SOUND PRESSURE LEVEL ~ 134 DB (10 FT RADII)



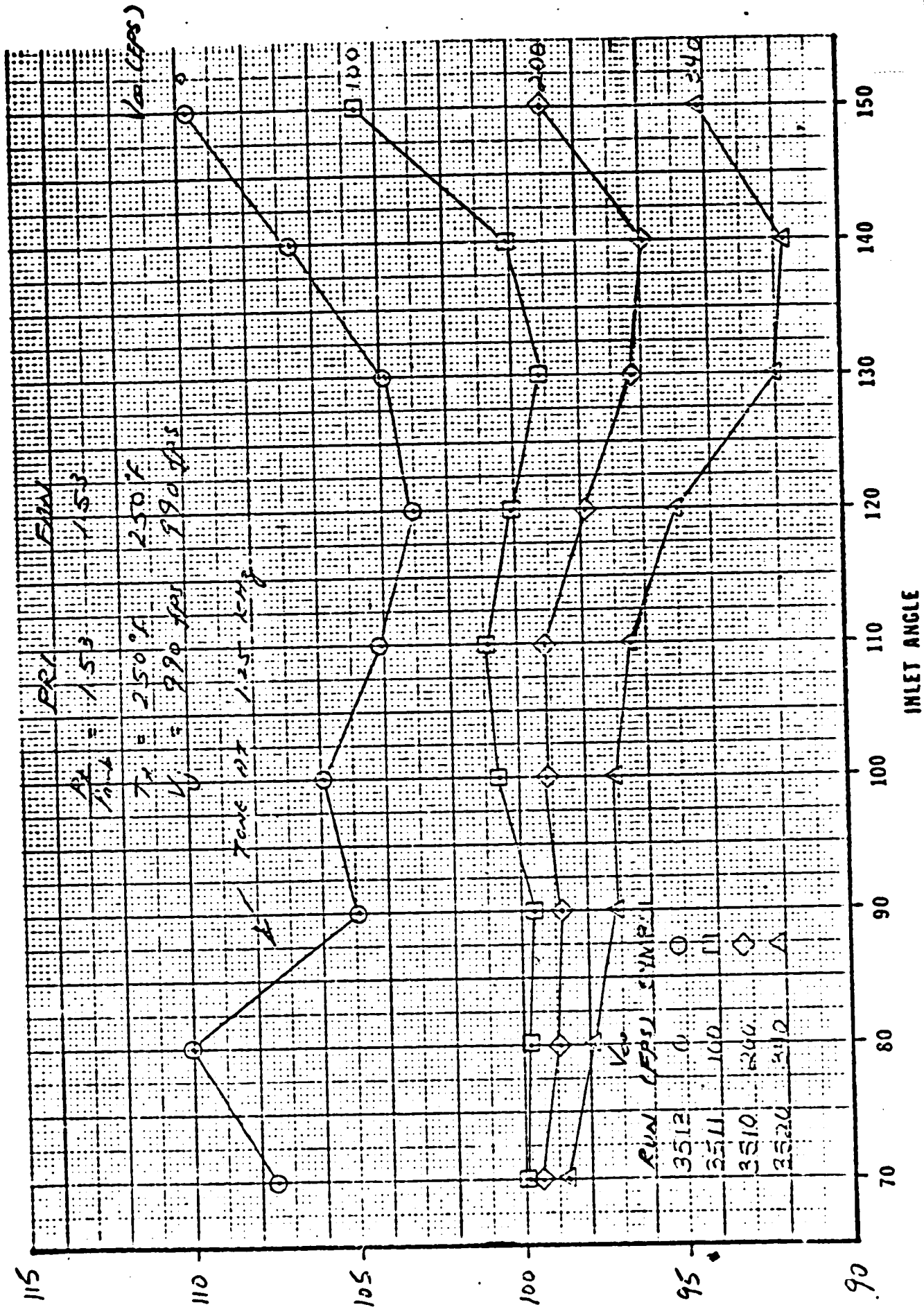
DIRECTIVITY

0.75 AR CONNULAR NOZZLE WITH EJECTOR V_{00} (FPS)



DIRECTIVITY

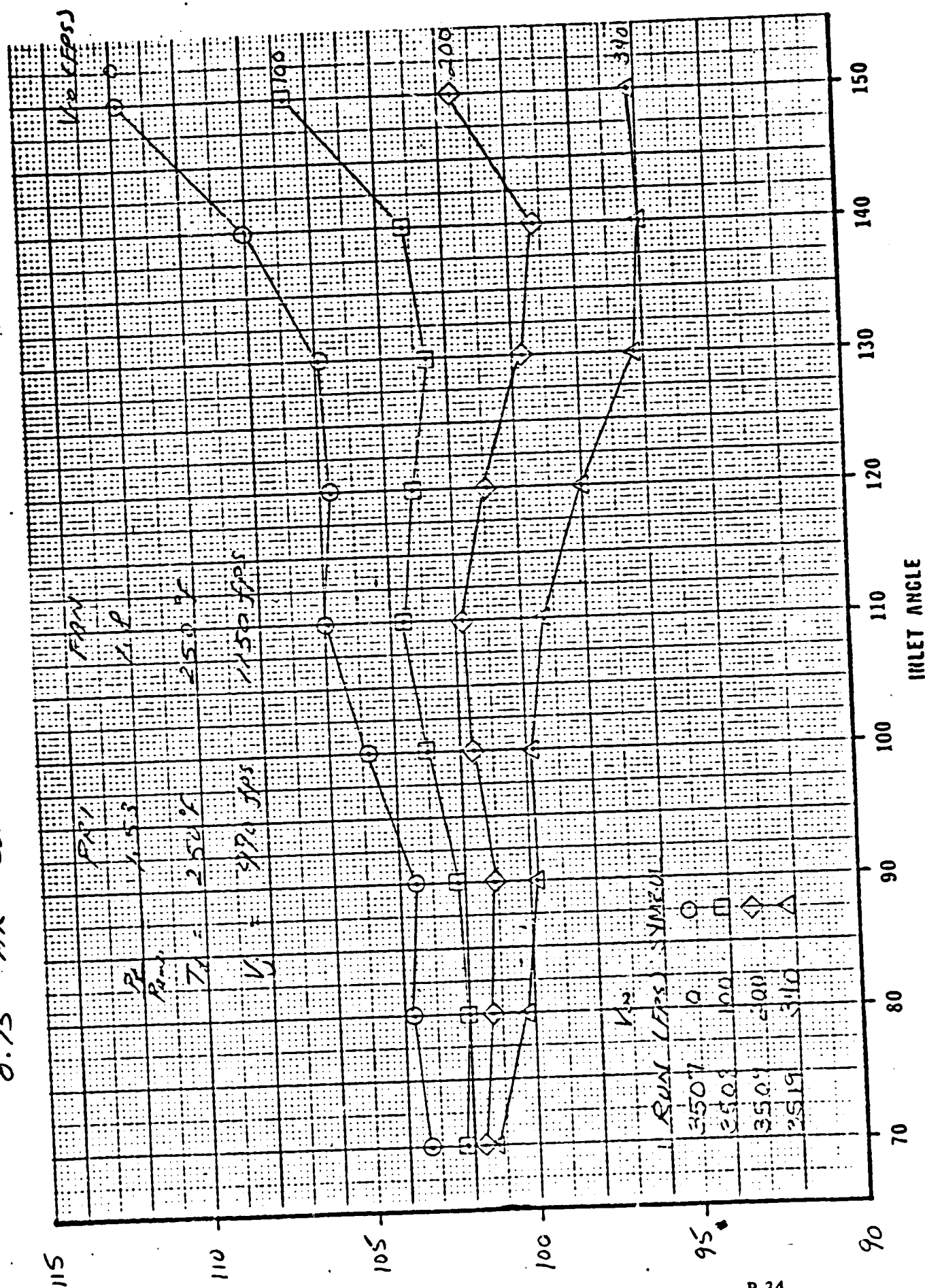
0.75 AR COAXIAL NOZZLE WITH EJECTOR



OVERALL SOUND PRESSURE LEVEL ~ 88 (10 FT Radius)

DIRECTIVITY

0.75 AR CONNULAR NOZZLE WITH EJECTOR



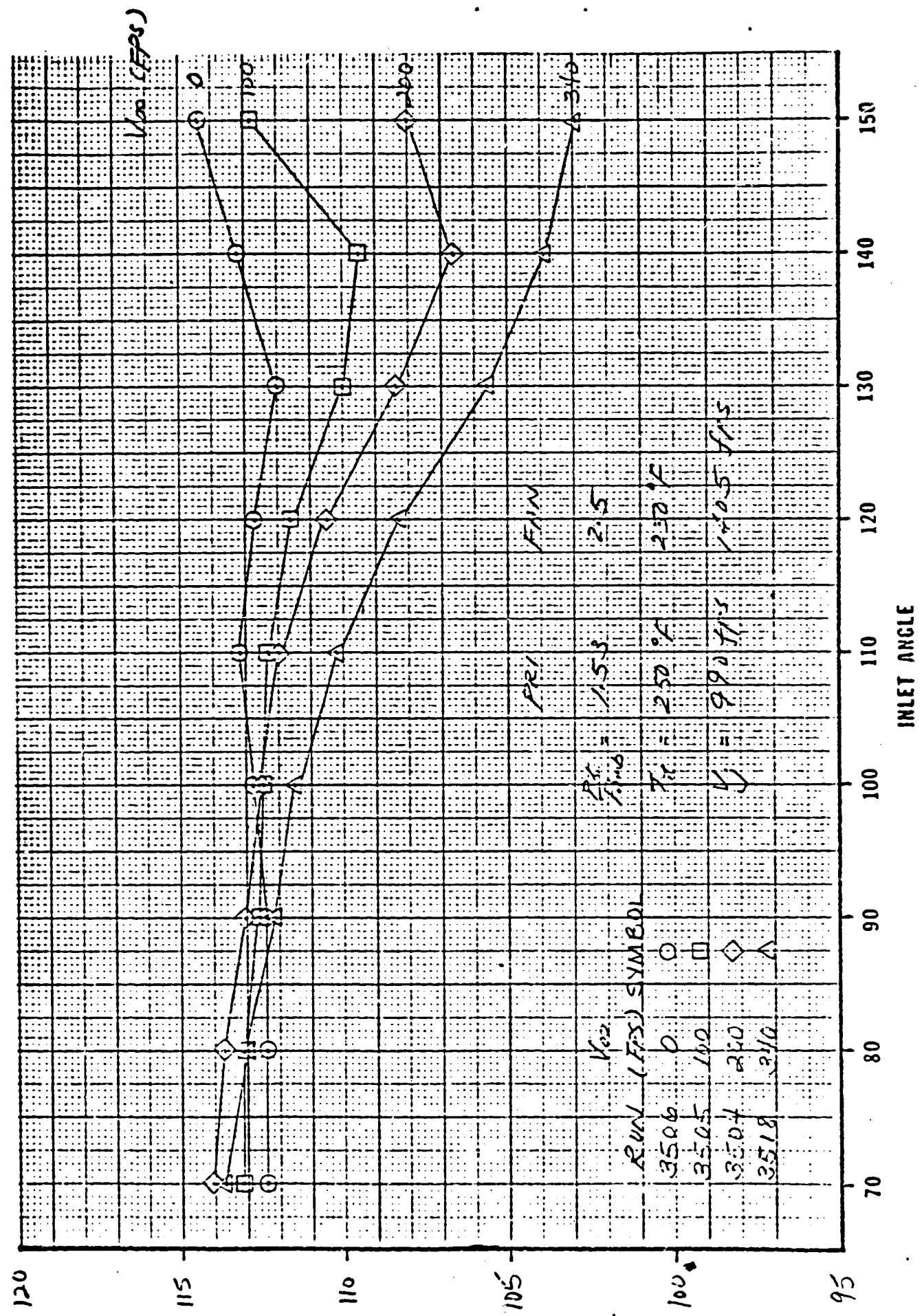
(10 FT RADII)

OVERALL SOUND PRESSURE LEVEL ~ dB

B-35

DIRECTIVITY

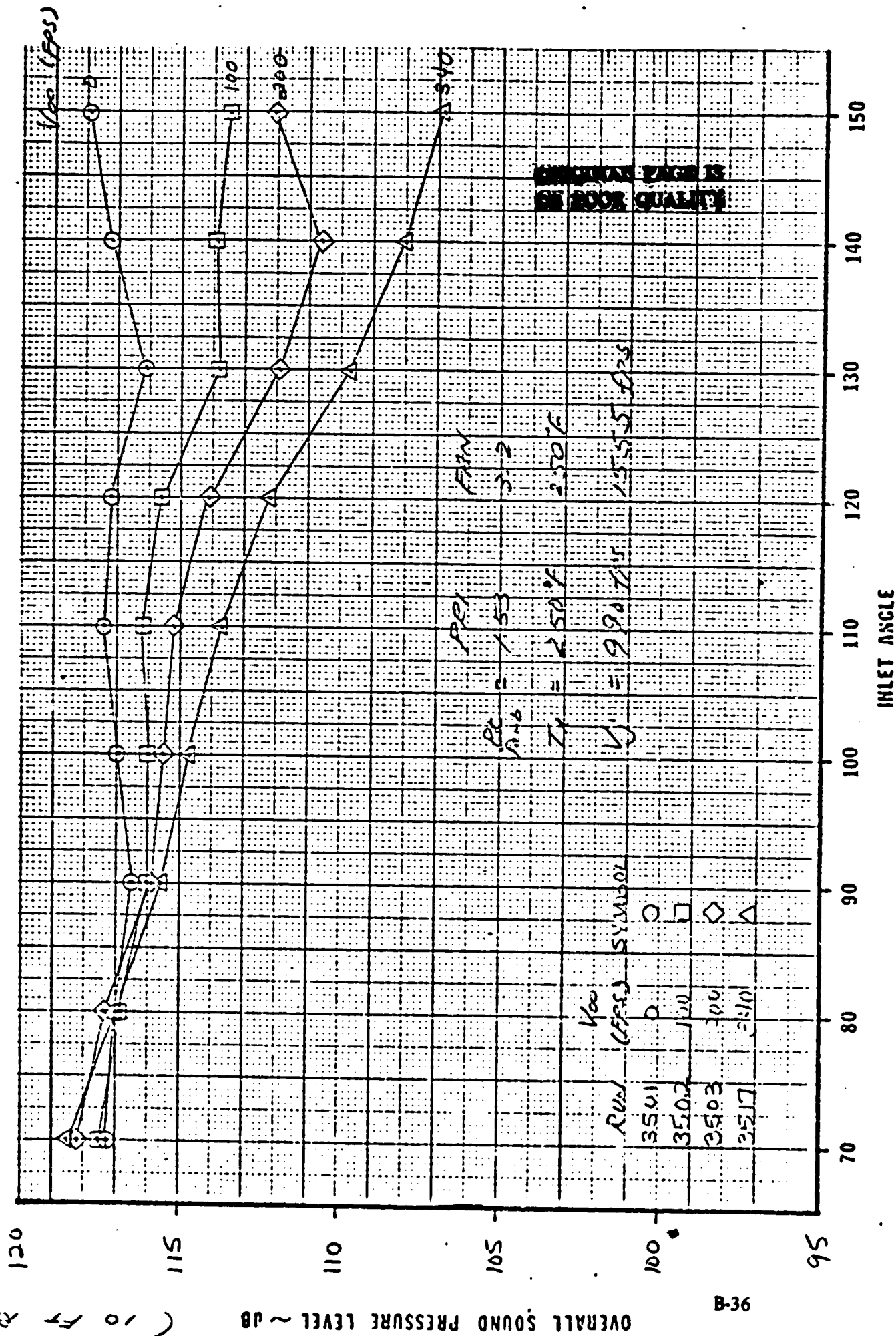
0.75 AR CONNULAR NOZZLE WITH EJECTOR



C-2

DIRECTIVITY

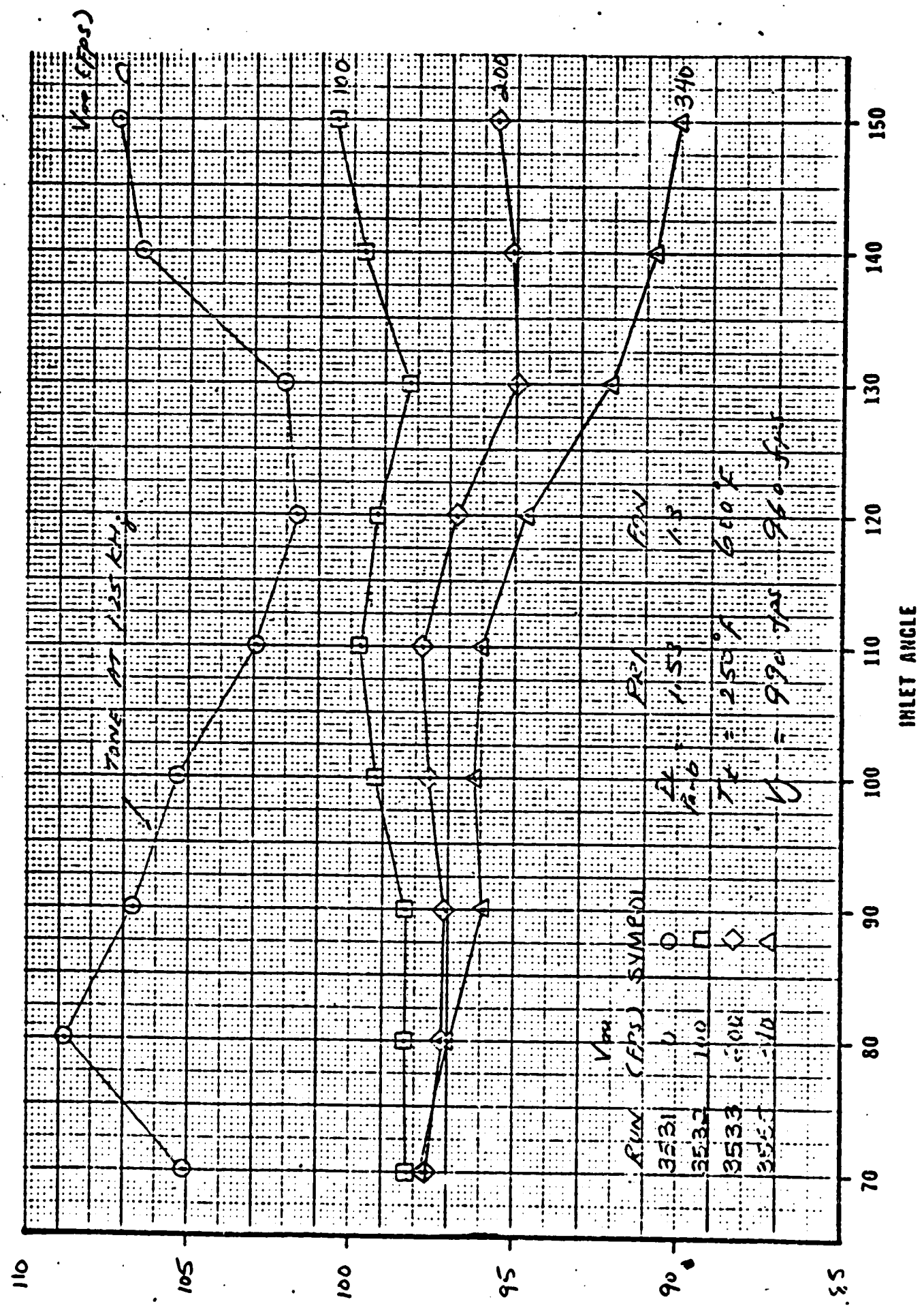
0.75 AR CONNUNAR, ORZLE WITH EJECTOR



(10 FT RADIUS)

DIRECTIVITY

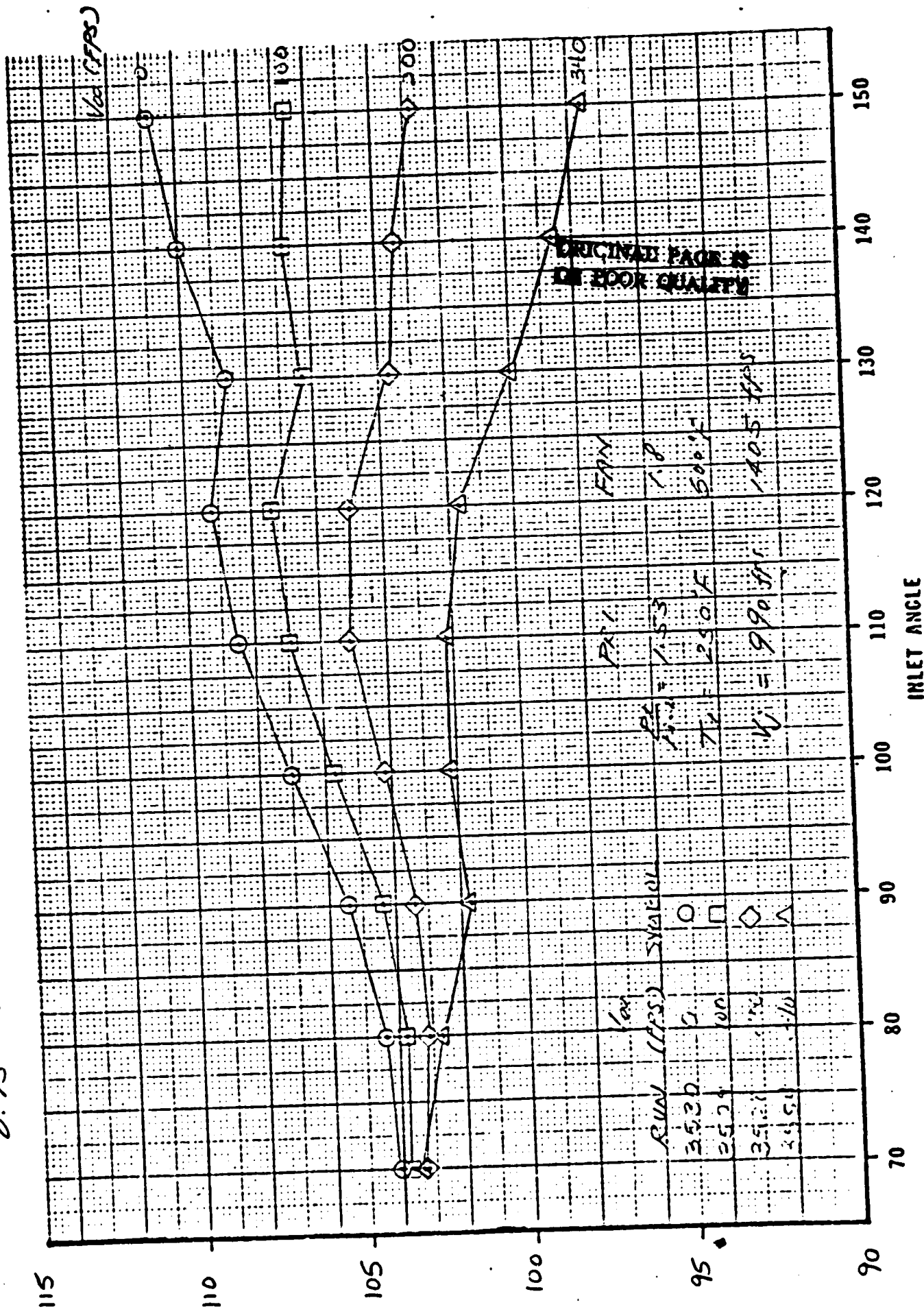
0.75 AR CONICAL NOZZLE WITH EJECTOR



DIRECTIVITY

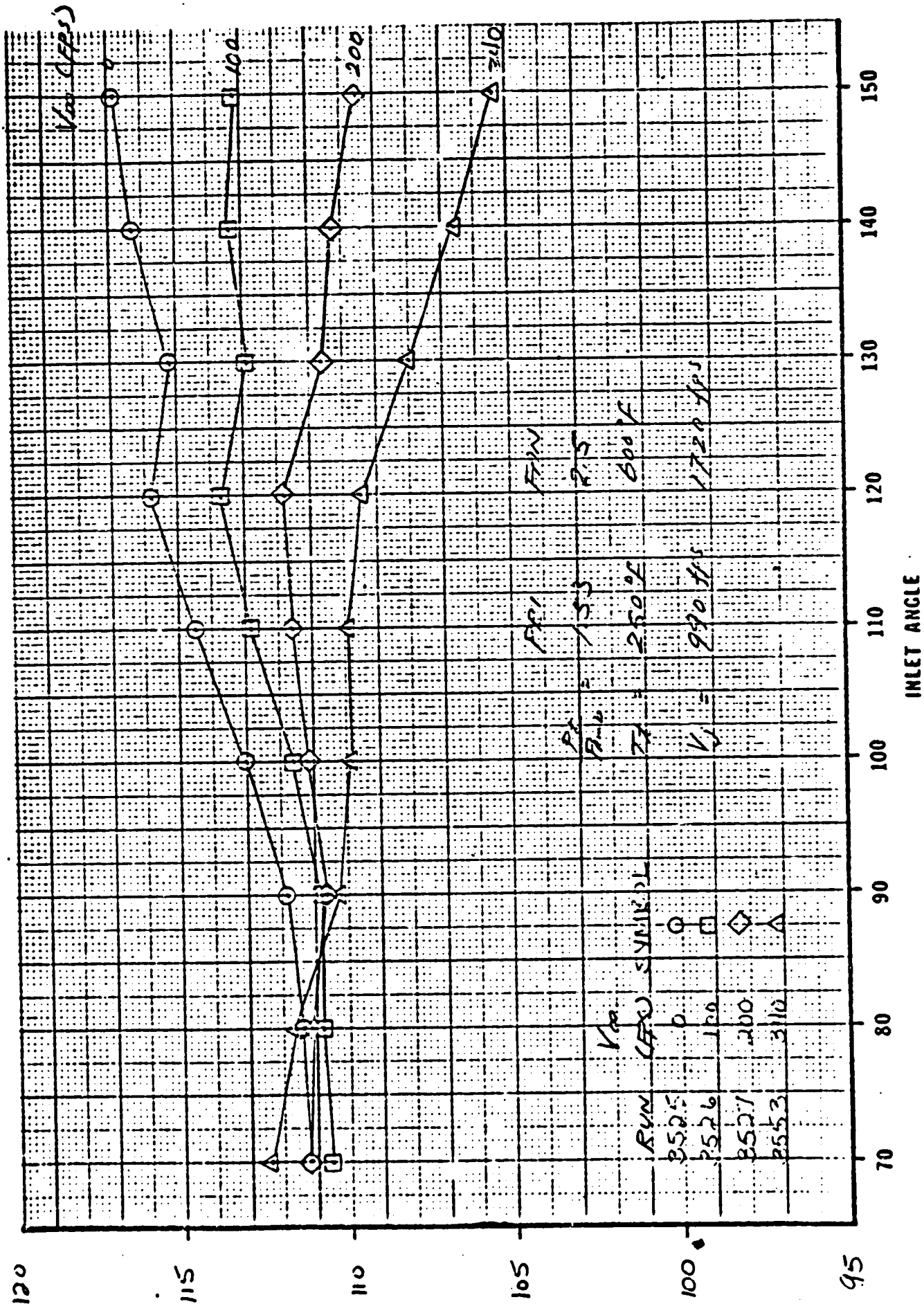
0.75 AR CONNULAR NOZLE WITH EJECTOR

OVERALL SOUND PRESSURE LEVEL ~ 10 FT RADII (10 FT RADII)



DIRECTIVITY

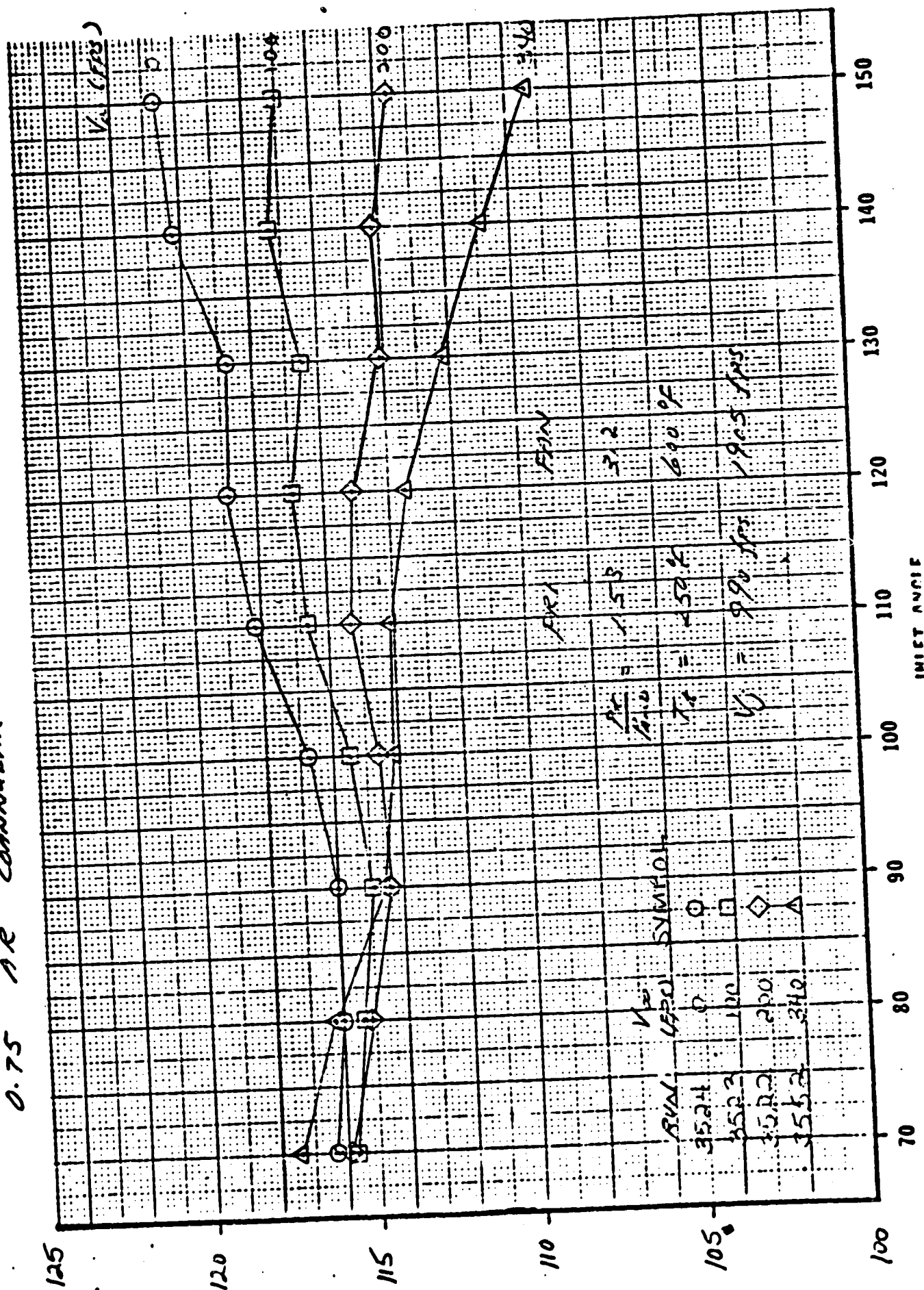
0.75 AR CONNULAR NOZZLE WITH EJECTOR



DIRECTIVITY

0.75 AR CONNULAR NOZZLE WITH EJECTOR

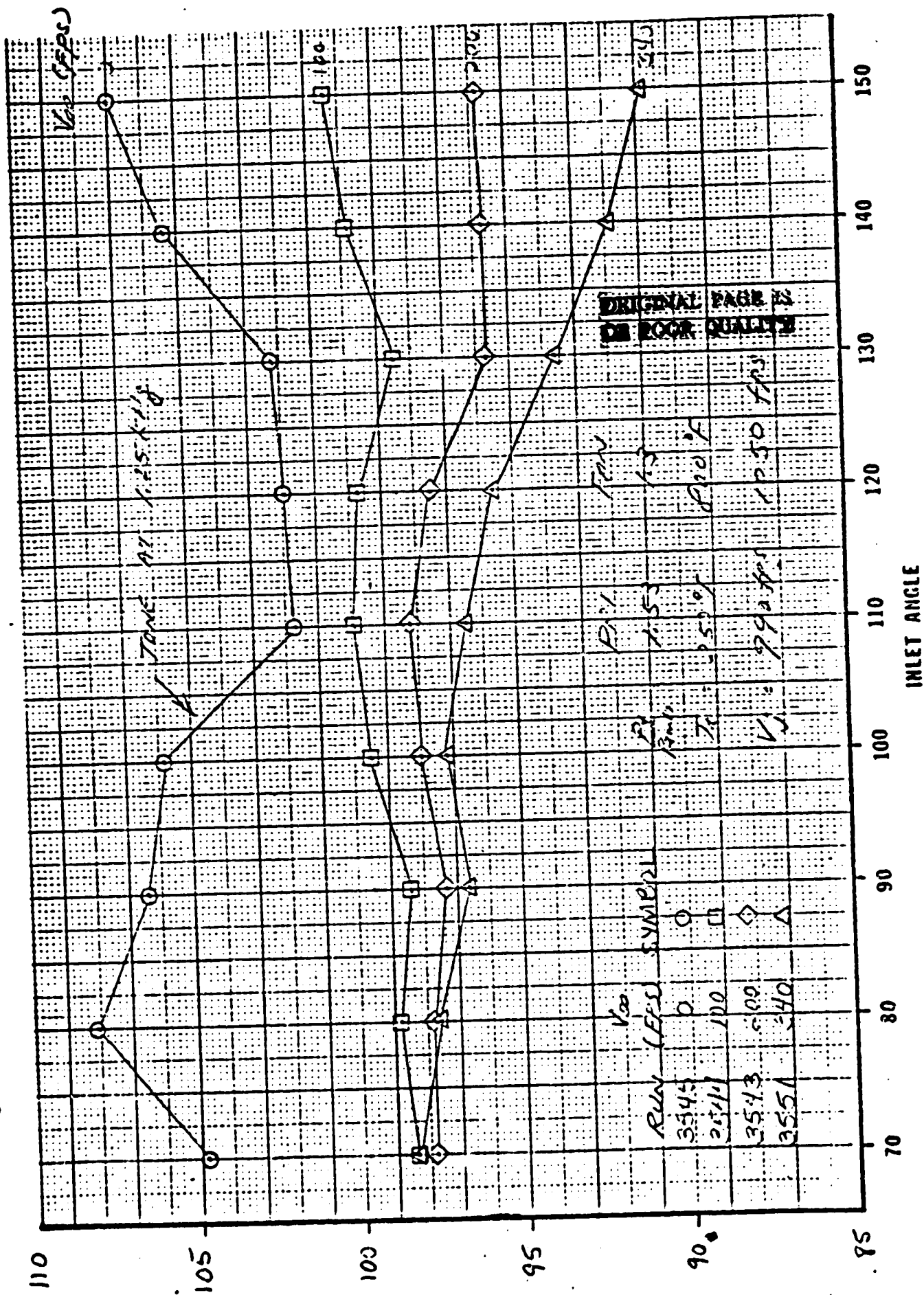
OVERALL SOUND PRESSURE LEVEL ~ 48 (10 FT RADIIUS)



DIRECTIVITY

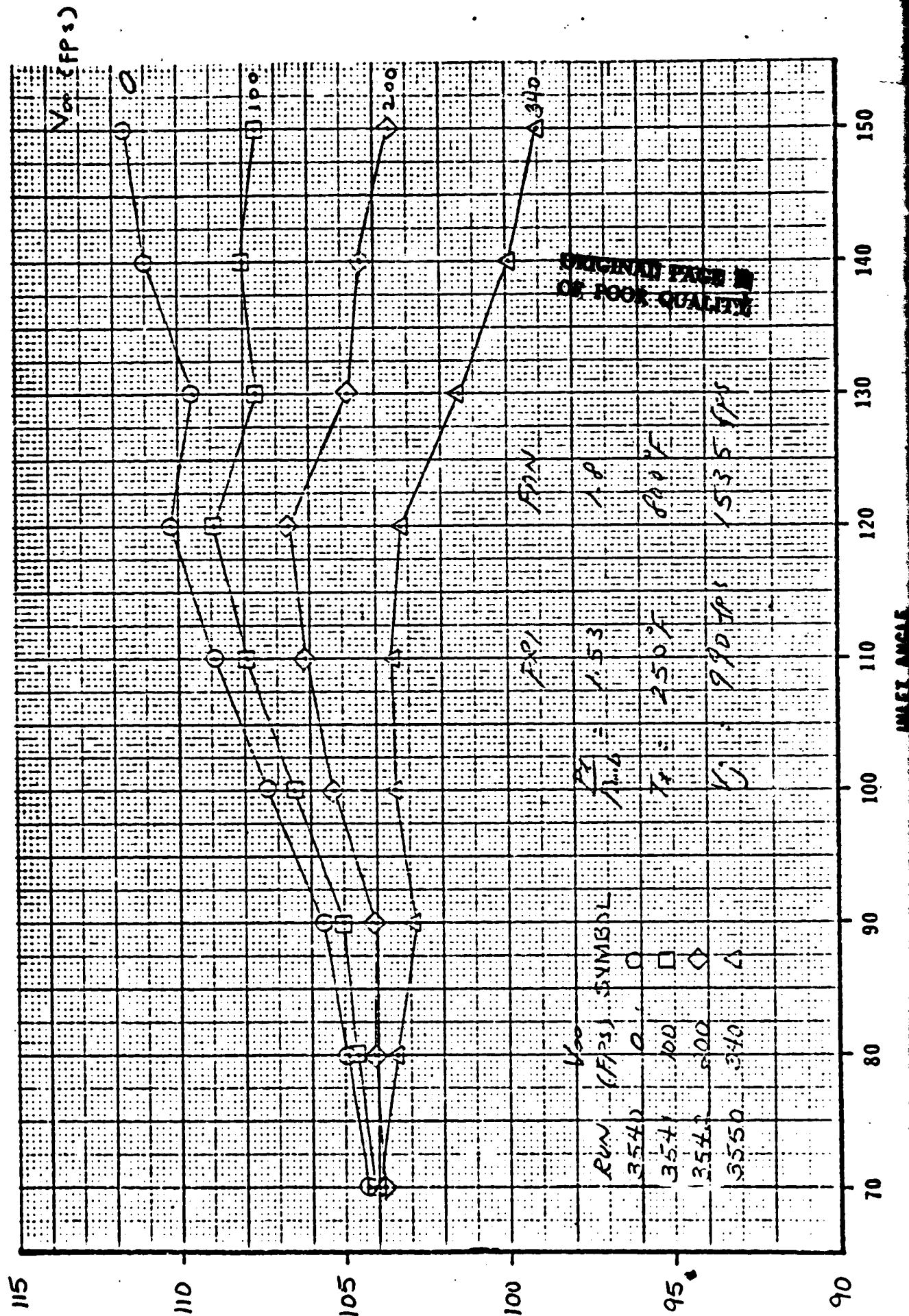
0.75 AR CONNULAR NOZZLE WITH EJECOR

(10 FT RADII)



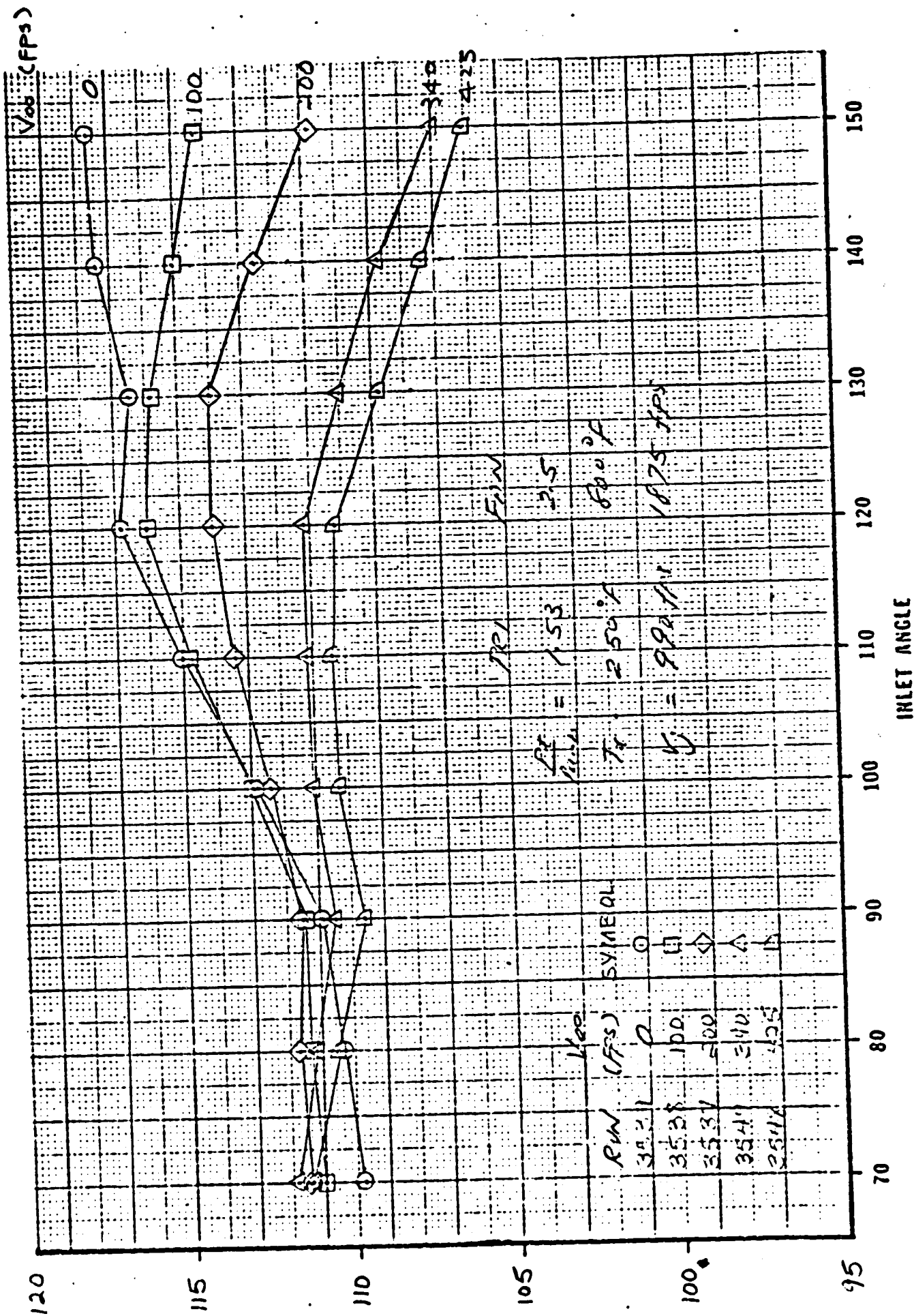
DIRECTIVITY

0.75 AR CANNULAR NOZZLE WITH EJECTOR



DIRECTIVITY

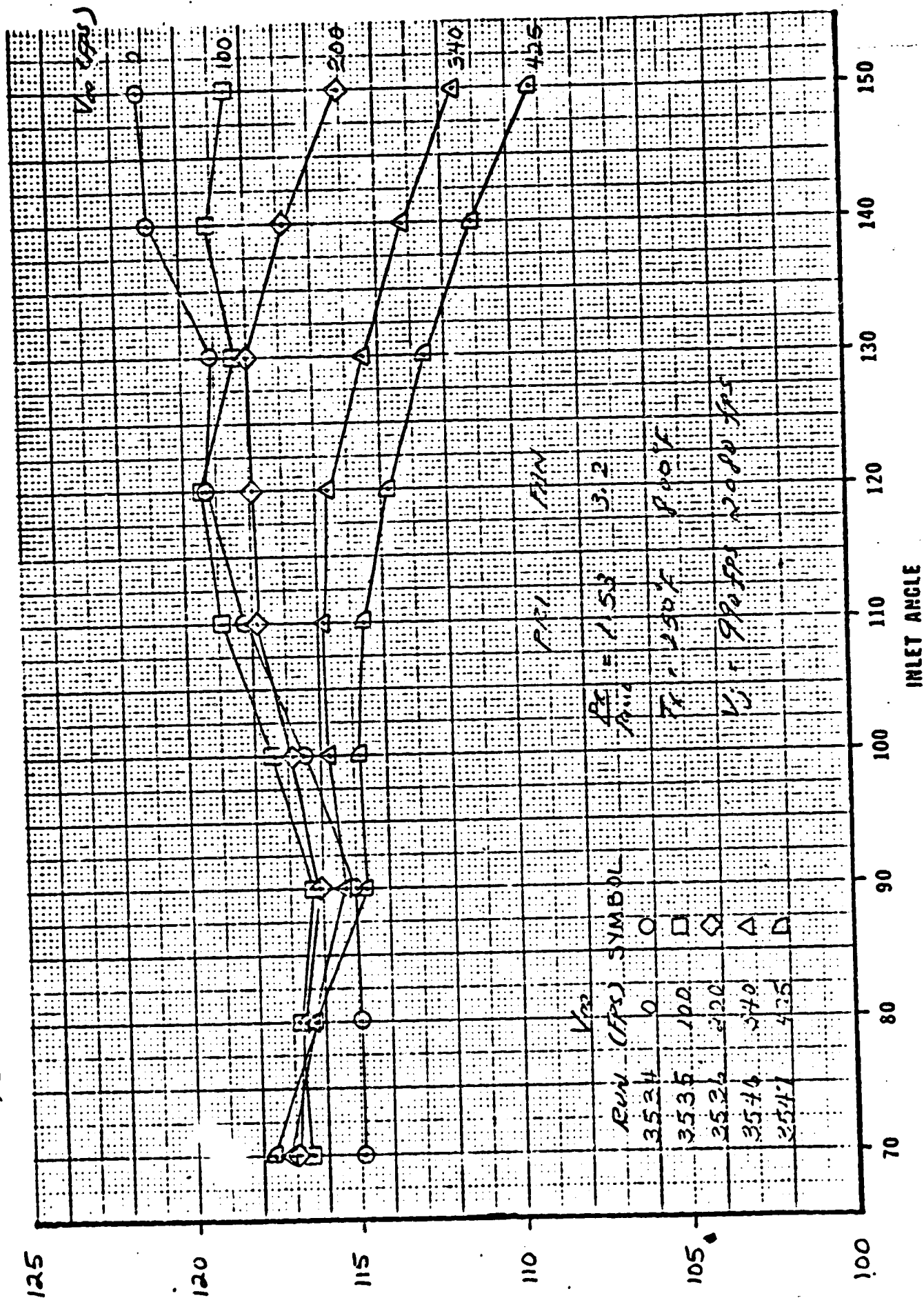
0.75 AR CONNULAR NOZZLE WITH EJECTOR



DIRECTIVITY

0.75 AR CONNULAR NOZZLE WITH EJECTOR

(10 FT RADII)



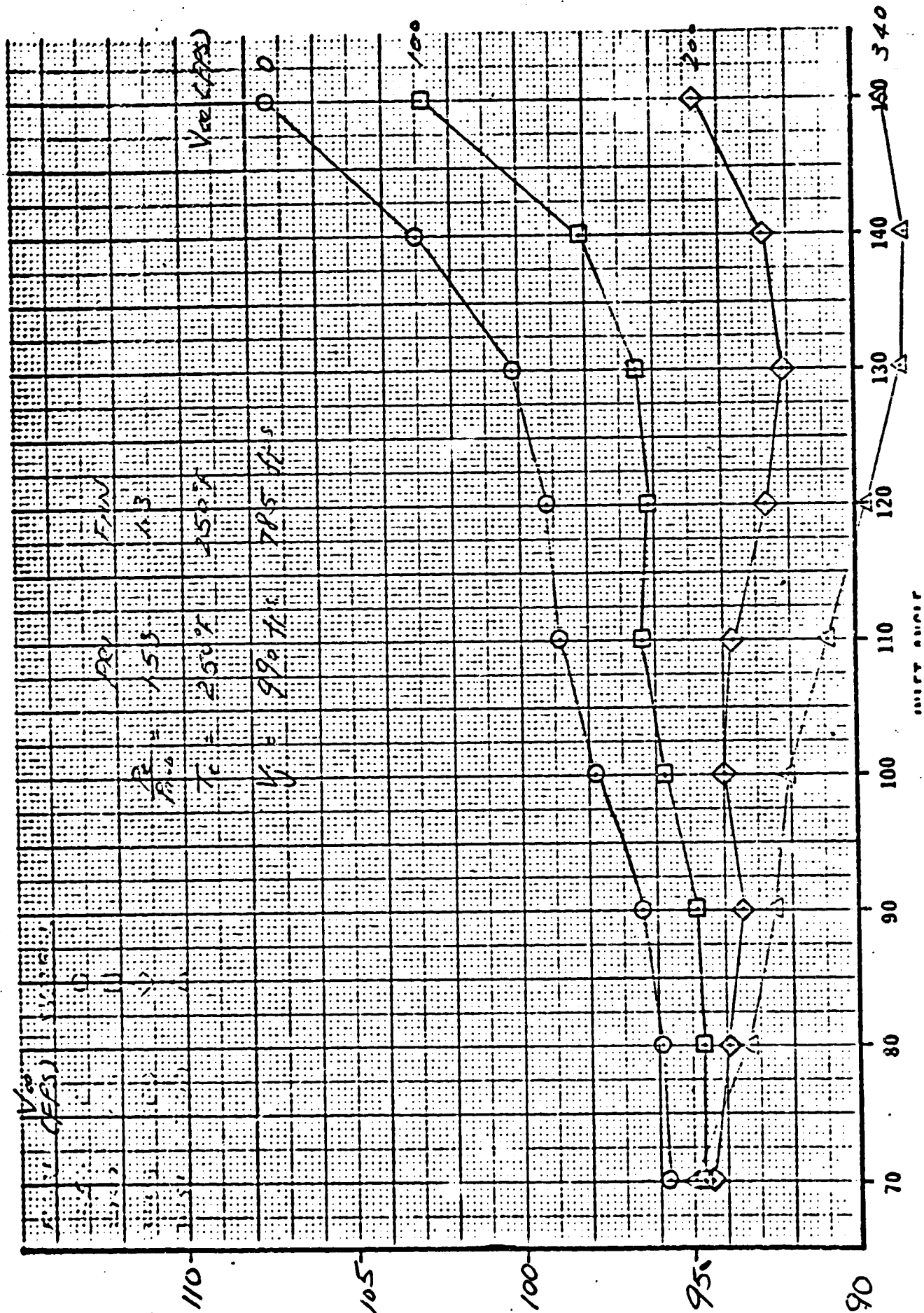
DIRECTIVITY

1.2 AR CONNULAR NOZZLE

(10 ft radius)

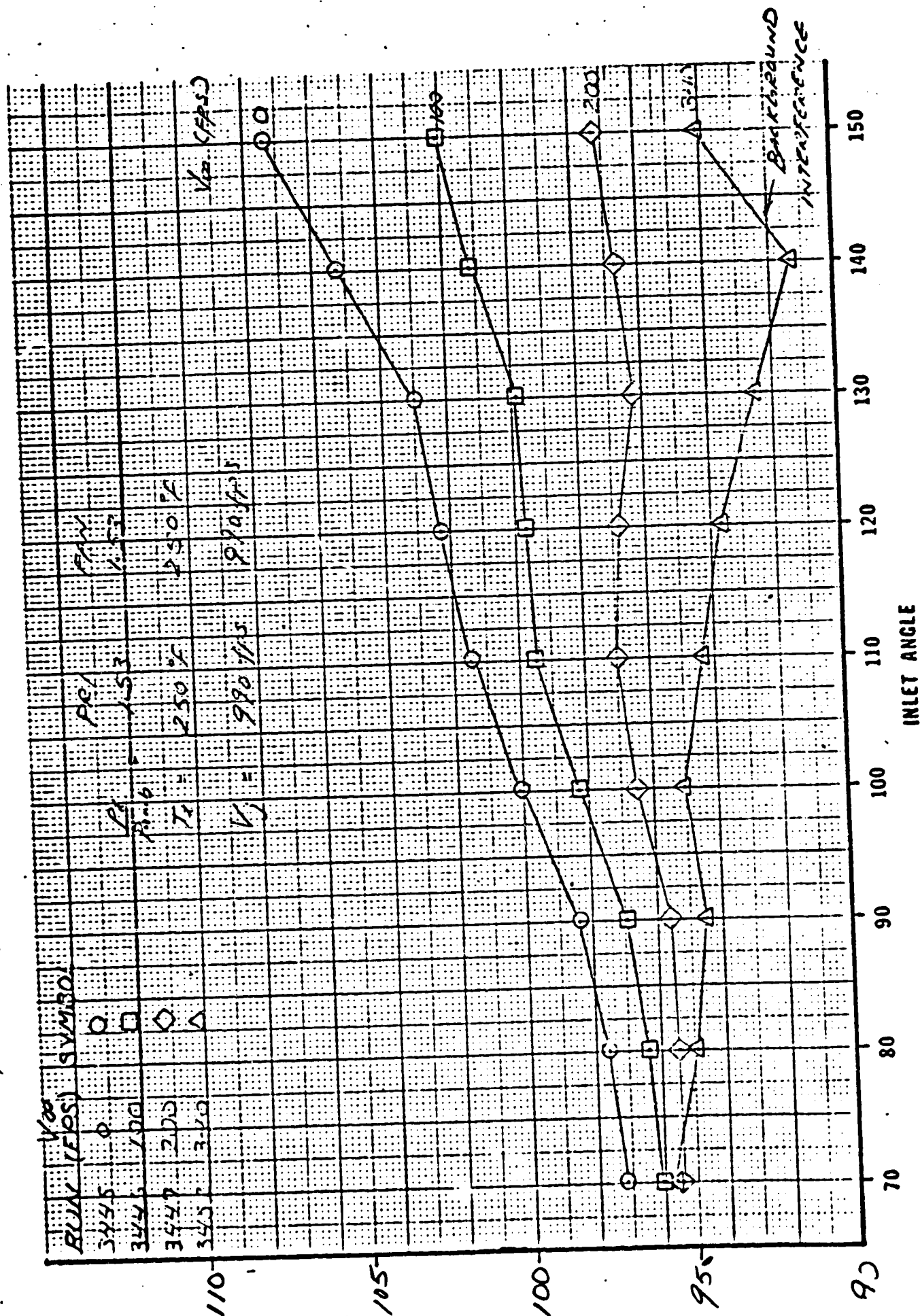
OVERALL SOUND PRESSURE LEVEL ~ 138

B-45



DIRECTIVITY

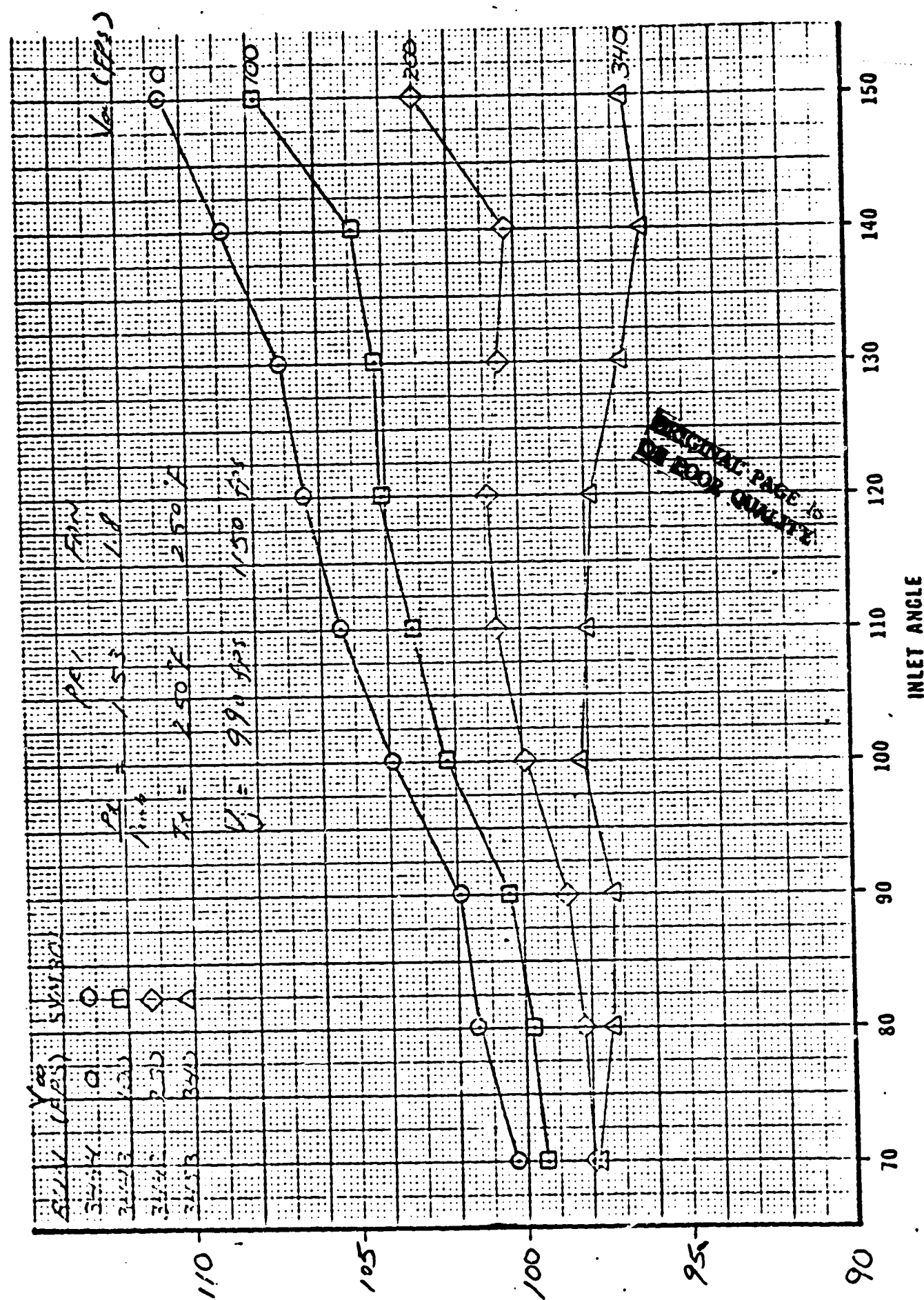
1.2 AR COANNULAR NOZZLE



DIRECTIVITY

1.2 AR CONNULAR NOZZLE

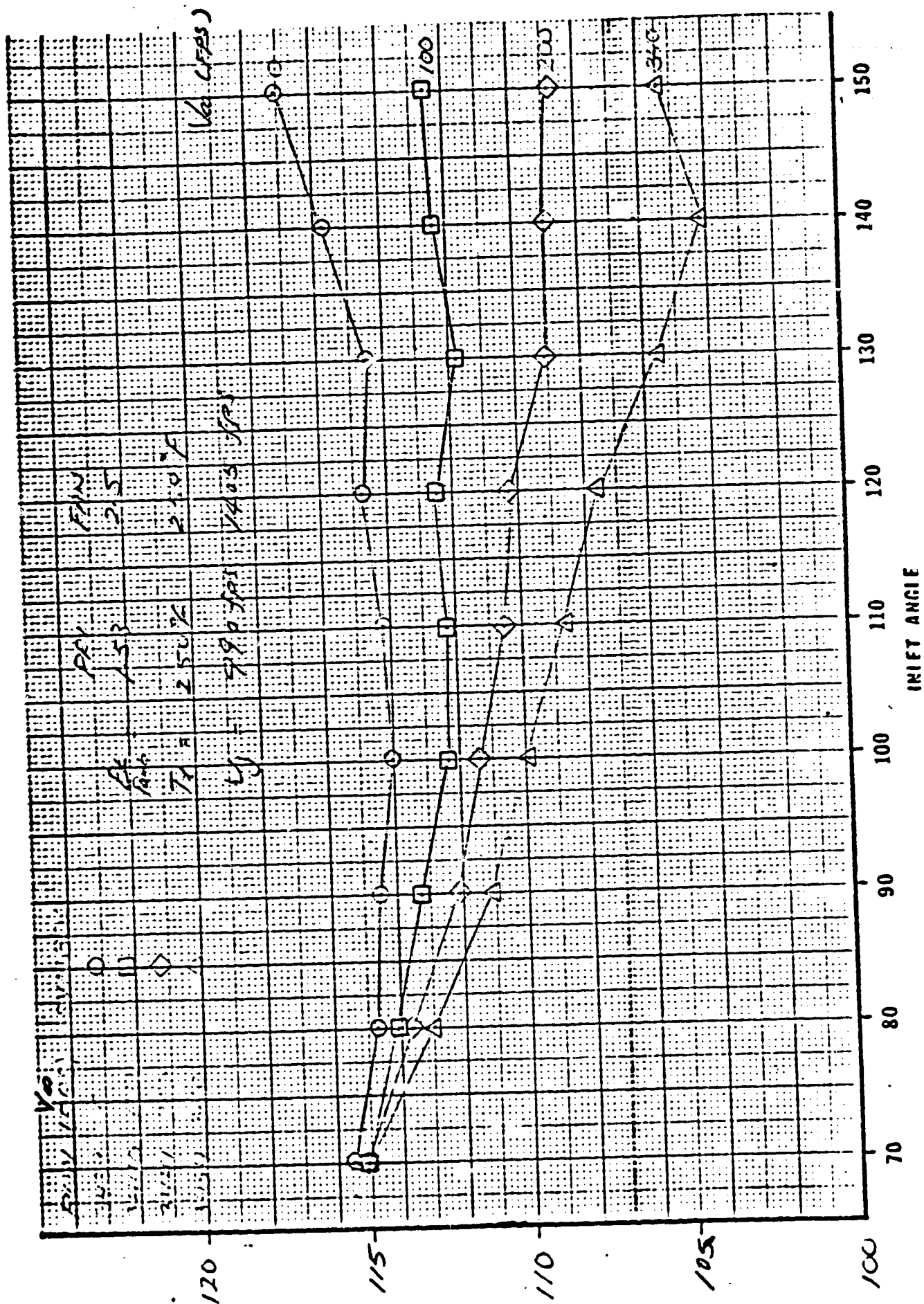
(10 FT Radius)



DIRECTIVITY

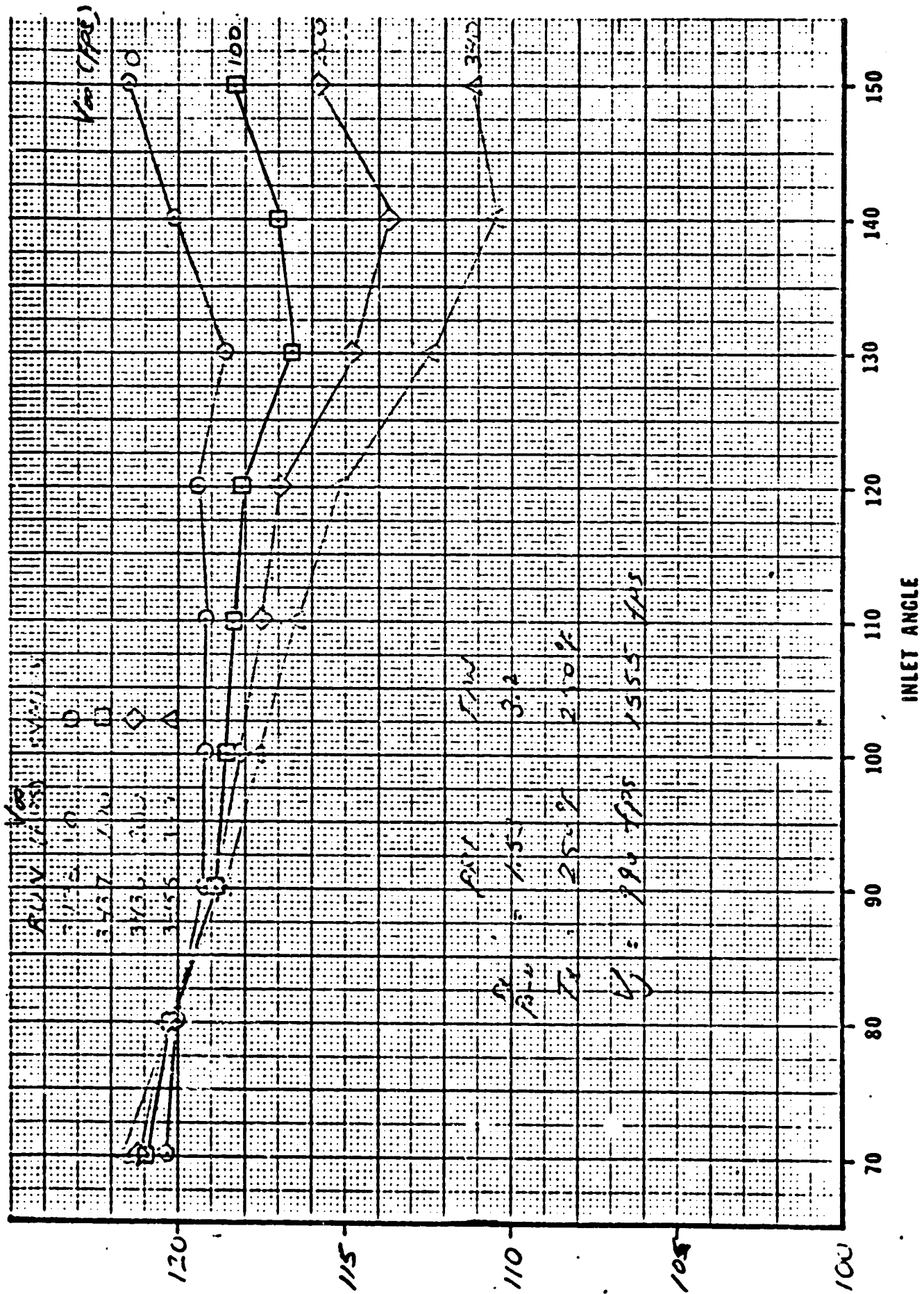
1.2 AR CORNUCULAR NOZZLE

(10 FT Radius) OVERALL SOUND PRESSURE LEVEL ~ 115 DB



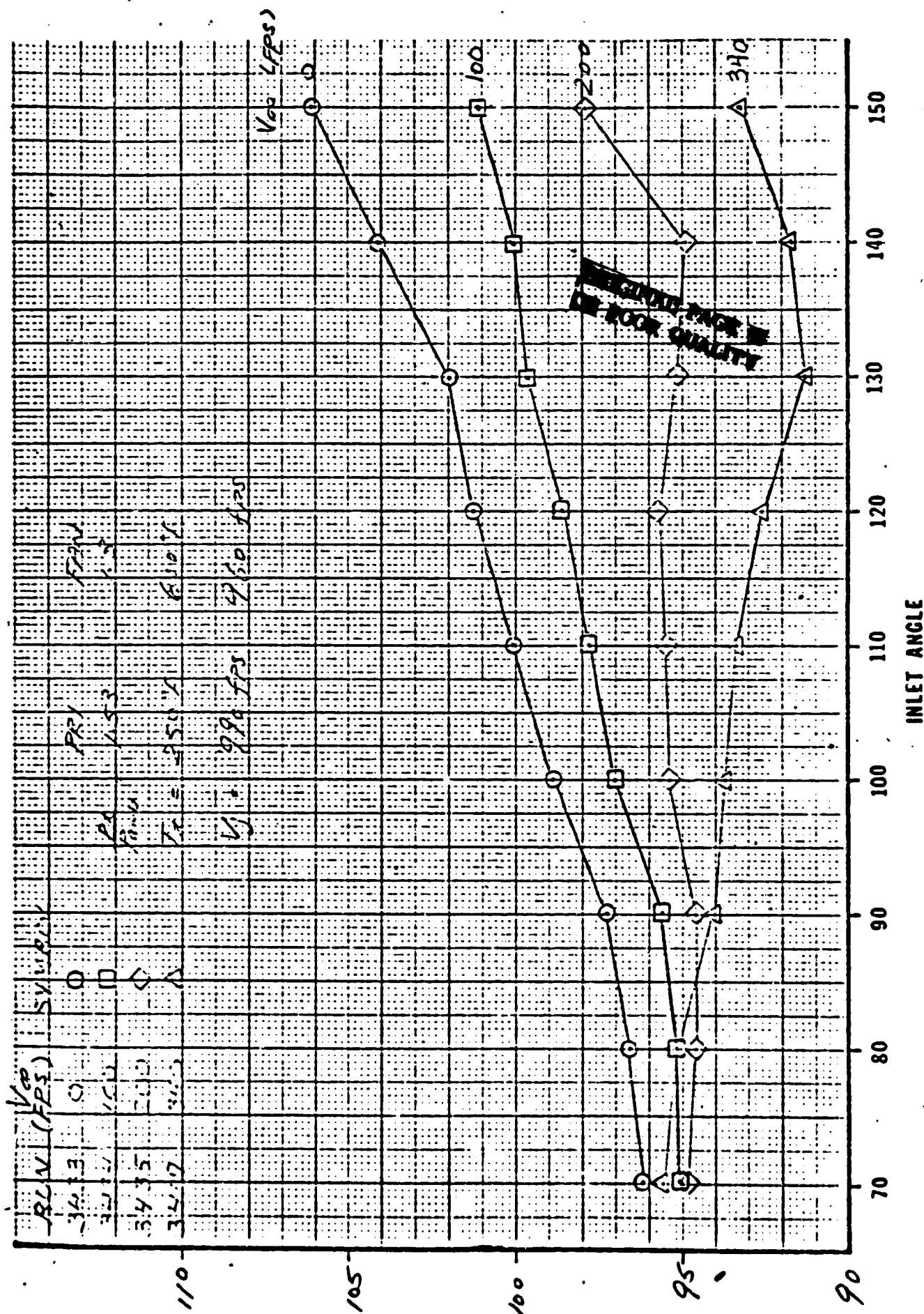
DIRECTIVITY

1.2 AR CONNULAR NOZZLE

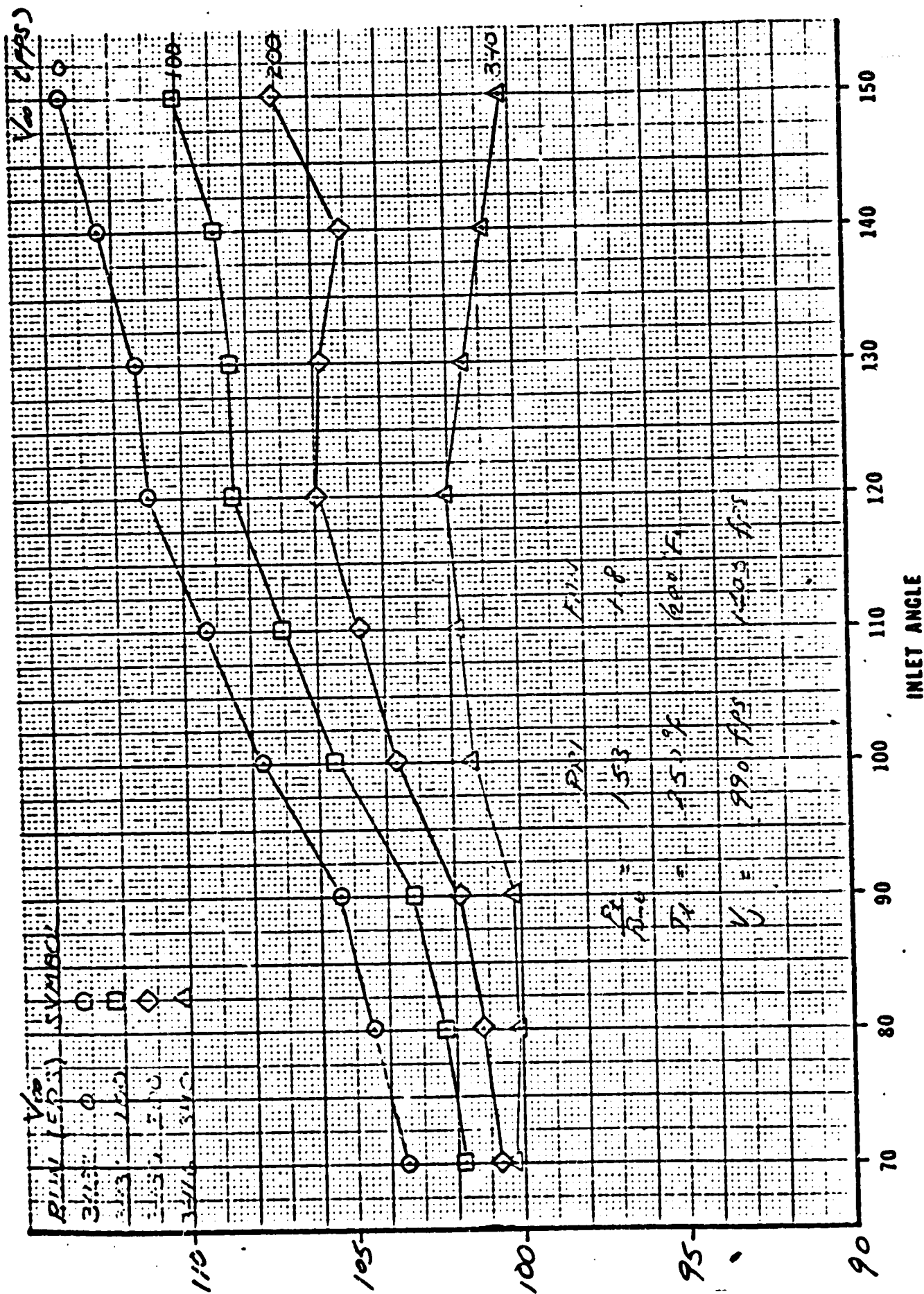


DIRECTIVITY

1.2 AR CONNULAR NOZZLE



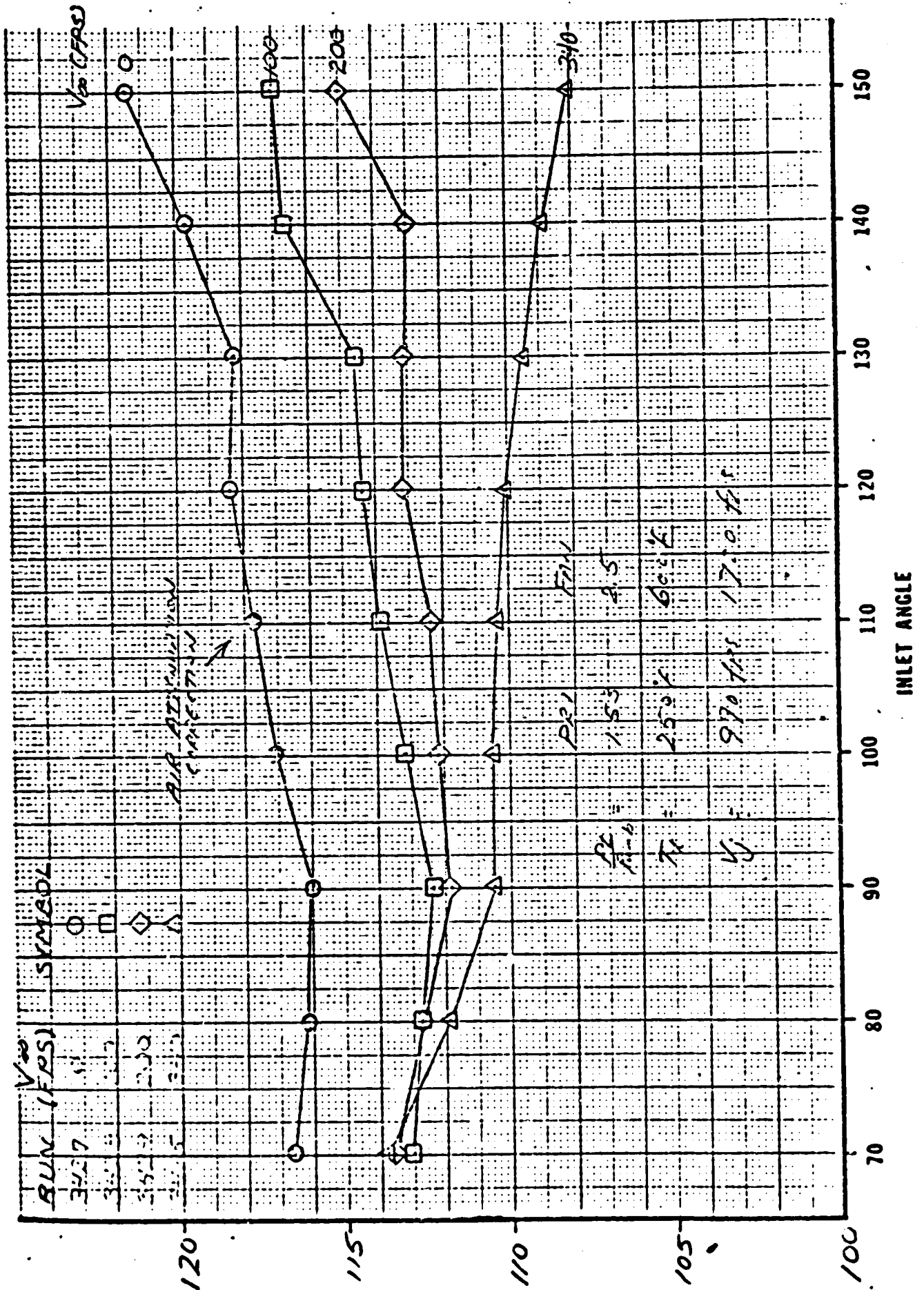
DIRECTIVITY 1.2 AR CONJUGAL NOZZLE



DIRECTIVITY

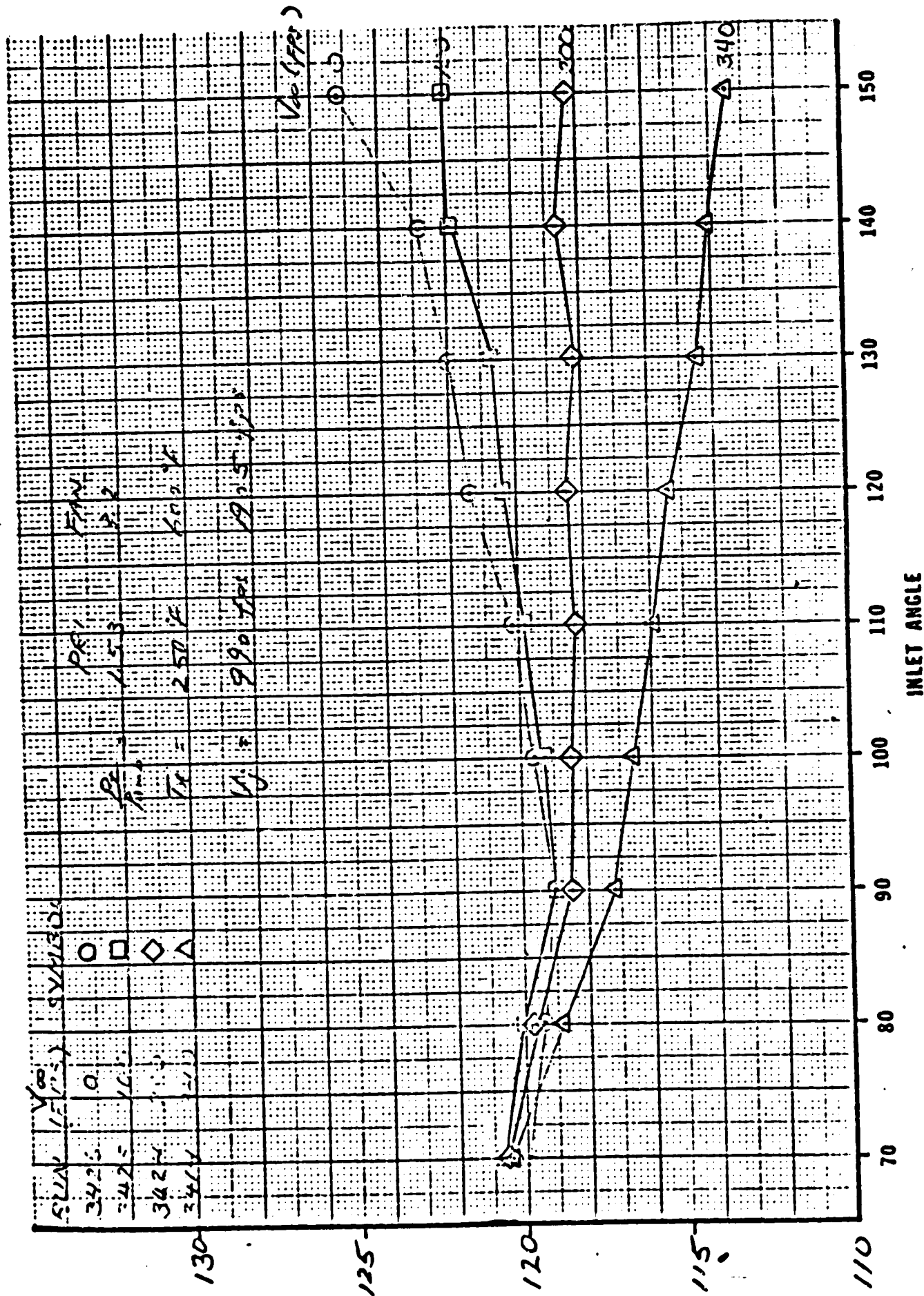
1.2 AR CONNULAR NOZZLES

(10 FT RADIUS)



DIRECTIVITY

1.2 AIR CHANNEL NOISE

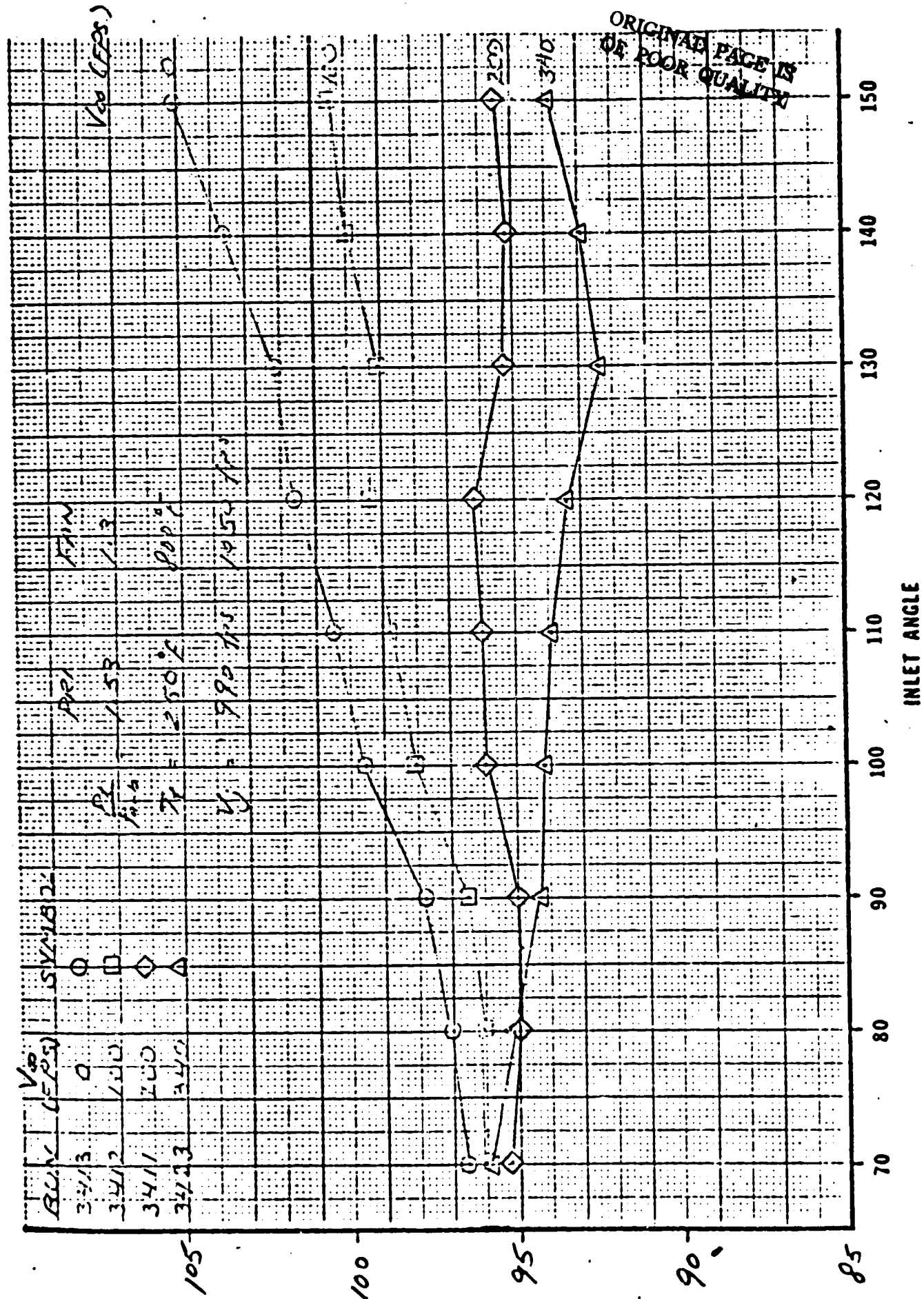


(10 ft radius)

OVERALL SOUND PRESSURE LEVEL ~ dB

ES-B

DIRECTIVITY 1.2 AR CONICAL NOZZLE

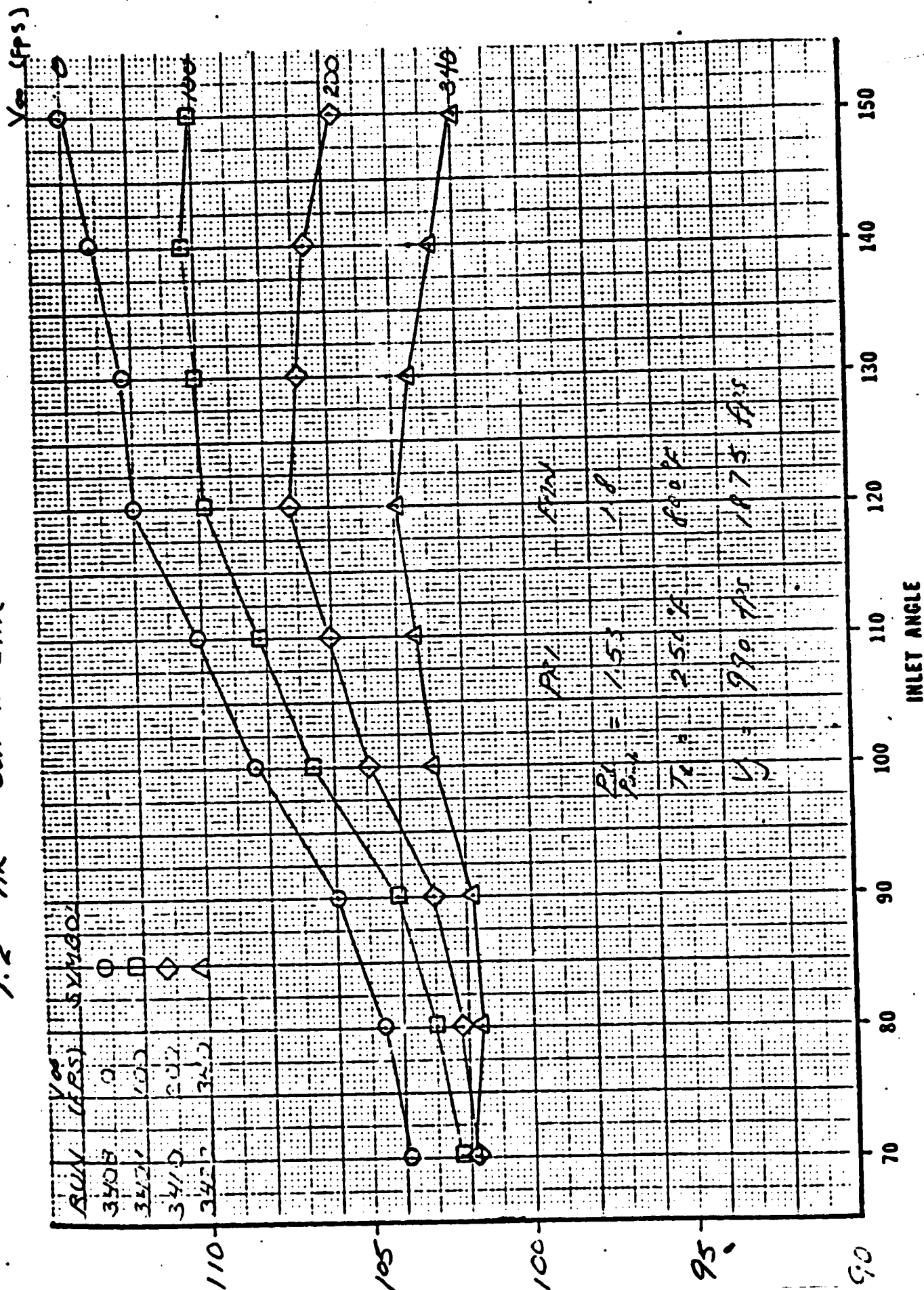


(10 ft Radius)

OVERALL SOUND PRESSURE LEVEL ~ dB

B-55

DIRECTIVITY 1.2 AR CONNULAR NOZZLE



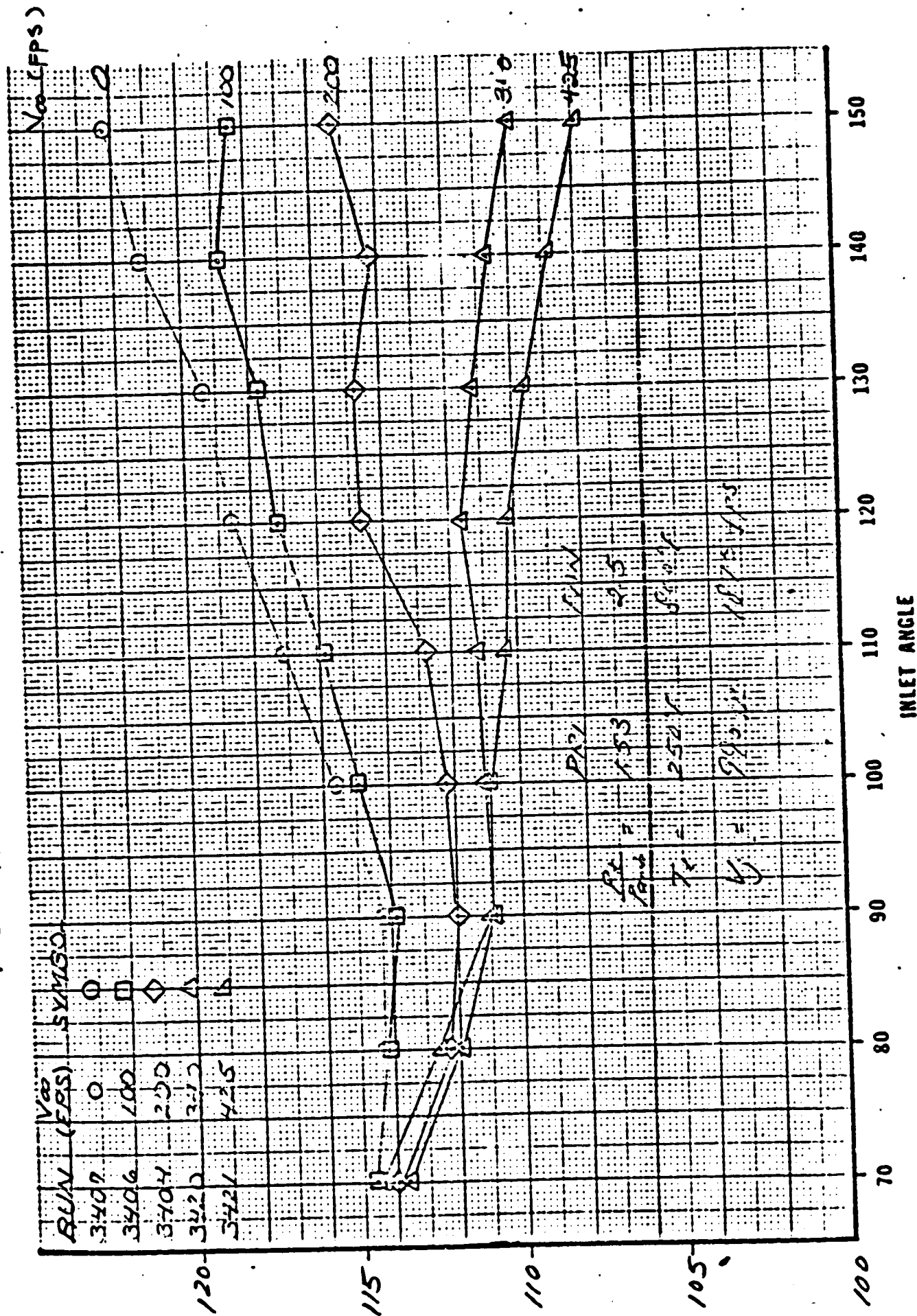
(10 FT RADIUS)

OVERALL SOUND PRESSURE LEVEL ~ DB

B-56

DIRECTIVITY

1.2 AR CONNULAR NOZZLE

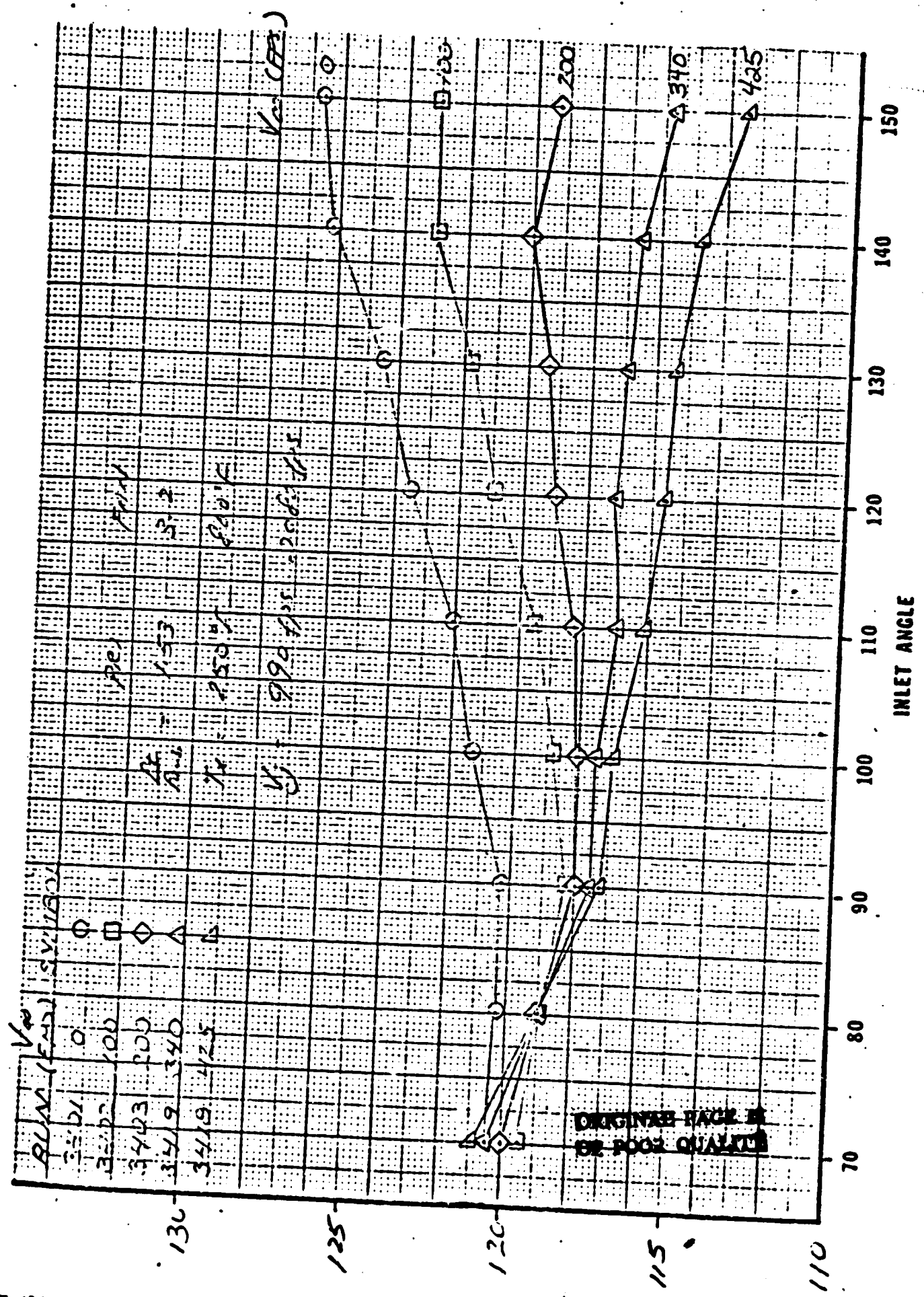


(10 FT Radius)

OVERALL SOUND PRESSURE LEVEL ~ dB

B-57

DIRECTIVITY 1.2 AR CONNULAR NOZZLE



RELATIVE VELOCITY EFFECT ON JET NOISE

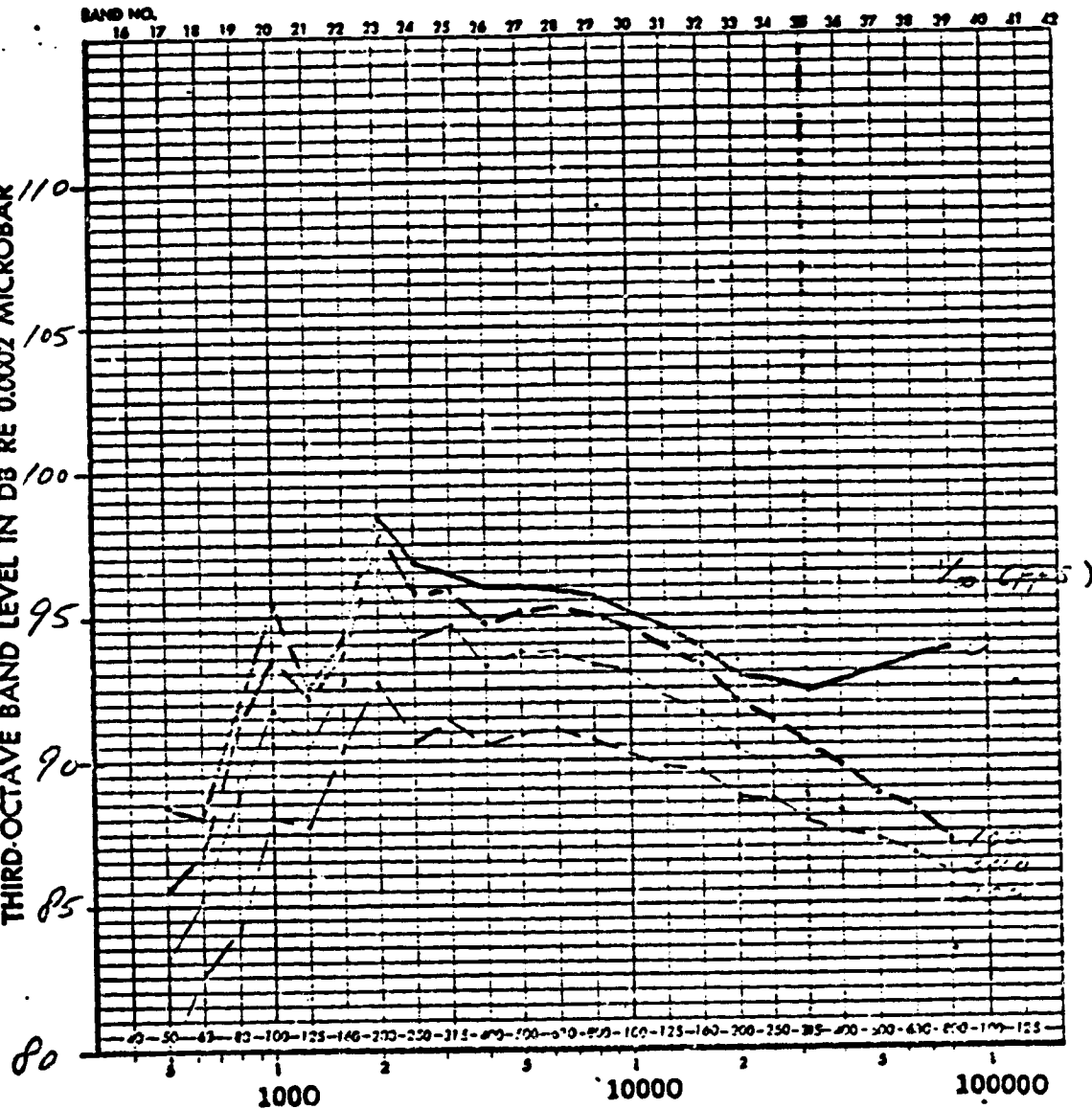
CONVERGENT NOZZLE

$\theta = 90^\circ$

ADD 45 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3610	1405	600	/		0
- - -	3607					100
—	3606					200
- - -	3613	✓	✓			340

$$\frac{P_f}{P_{f0}} = 1.8$$

NOTE:

* HIGH FREQUENCY UPLIFT

C-1

RELATIVE VELOCITY EFFECT ON JET NOISE

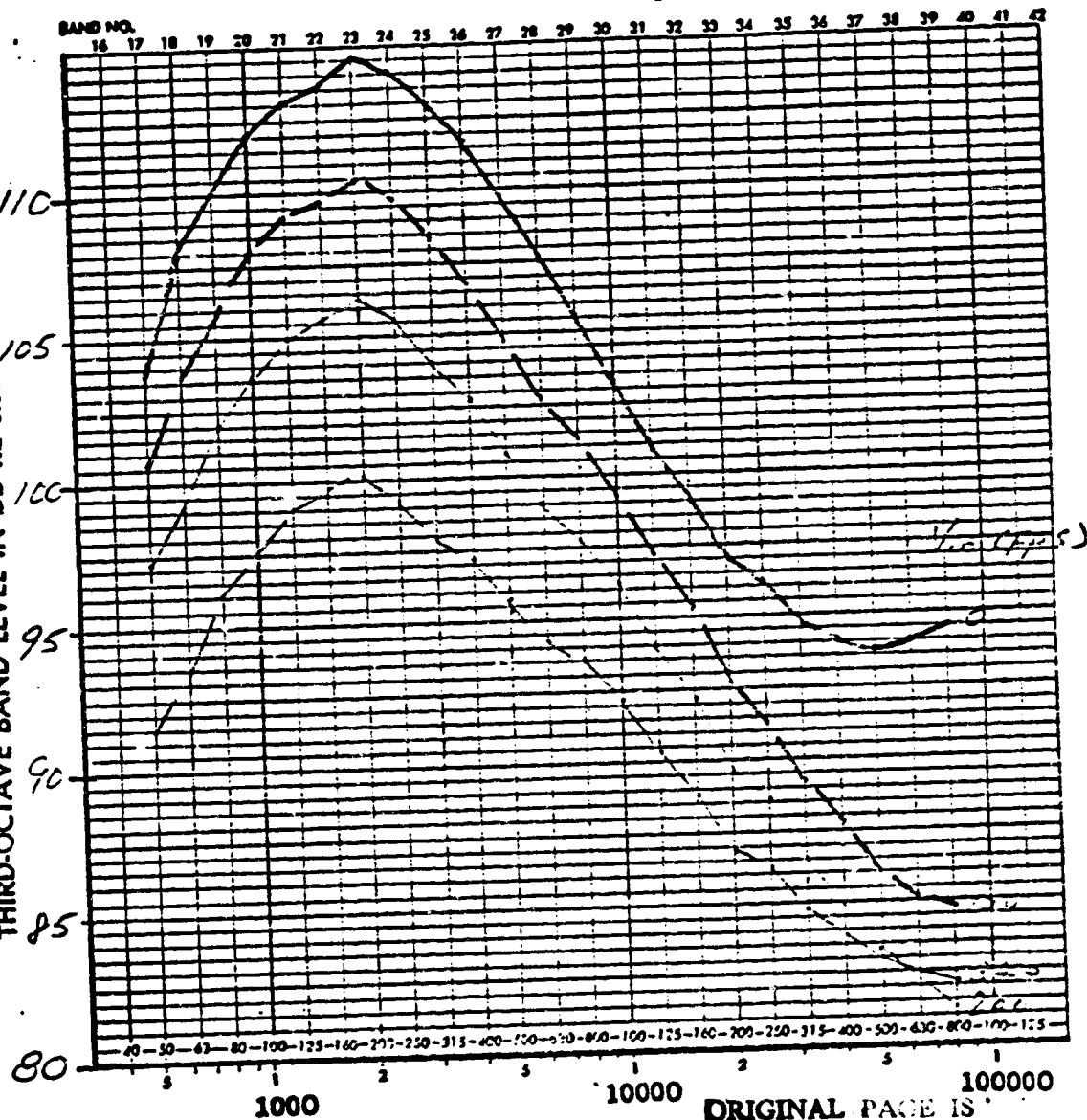
CONVERGENT NOZZLE

$\theta = 150^\circ$

ADD 4.9 DB TO OBTAIN OCTAVE LUND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



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FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3608	1205	600			0
-----	3607					100
————	3606					200
-----	3613					340

$$\frac{P_f}{P_{amb}} = 1.8$$

ORIGINAL PAGE IS
OF POOR QUALITY

RELATIVE VELOCITY EFFECT ON JET NOISE

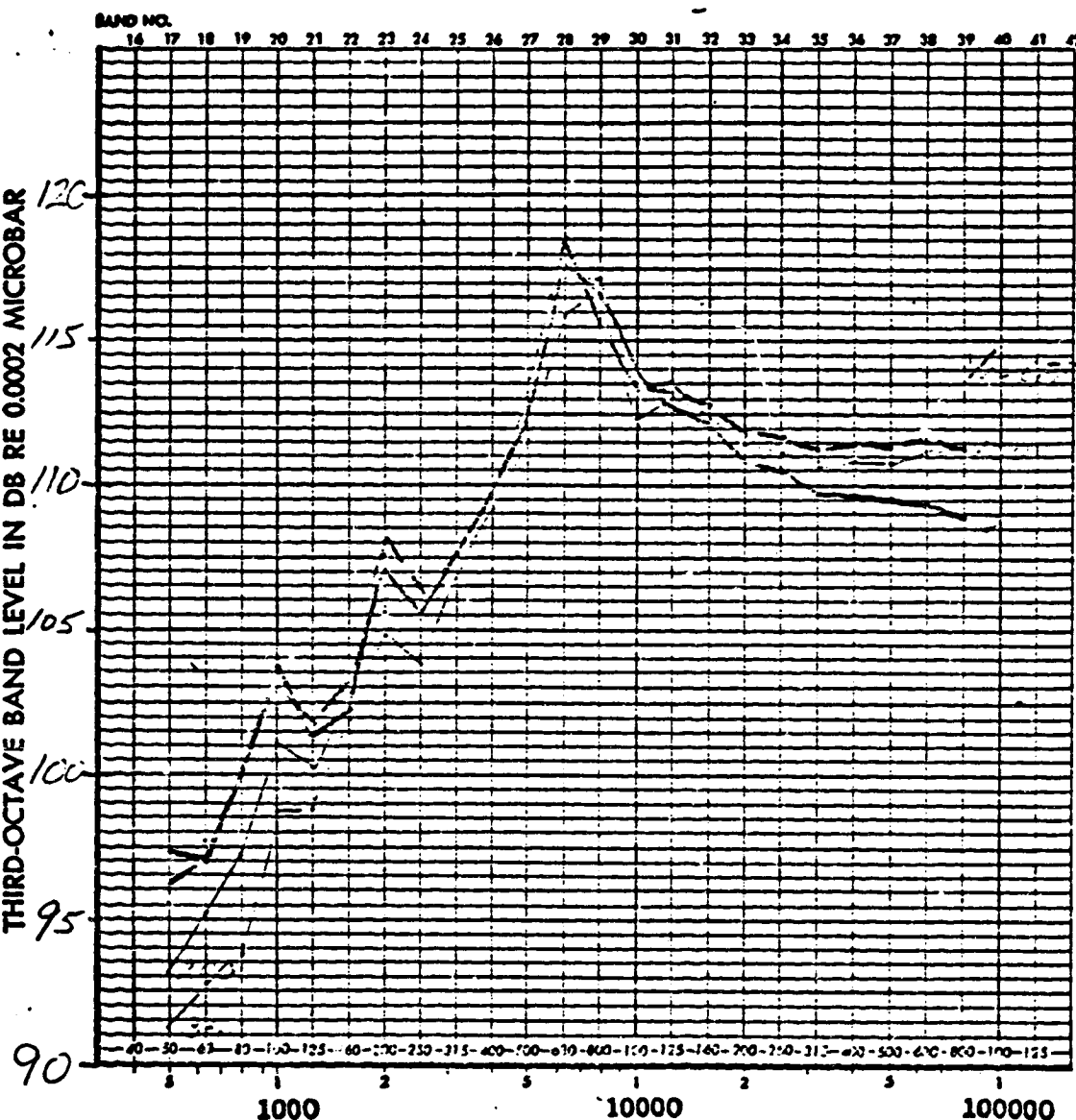
CONVERGENT NOZZLE

$\theta = 90^\circ$

ADD 47 DB TO OBTAIN BAND LEVEL

SOUND PRESSURE LEVEL ~10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

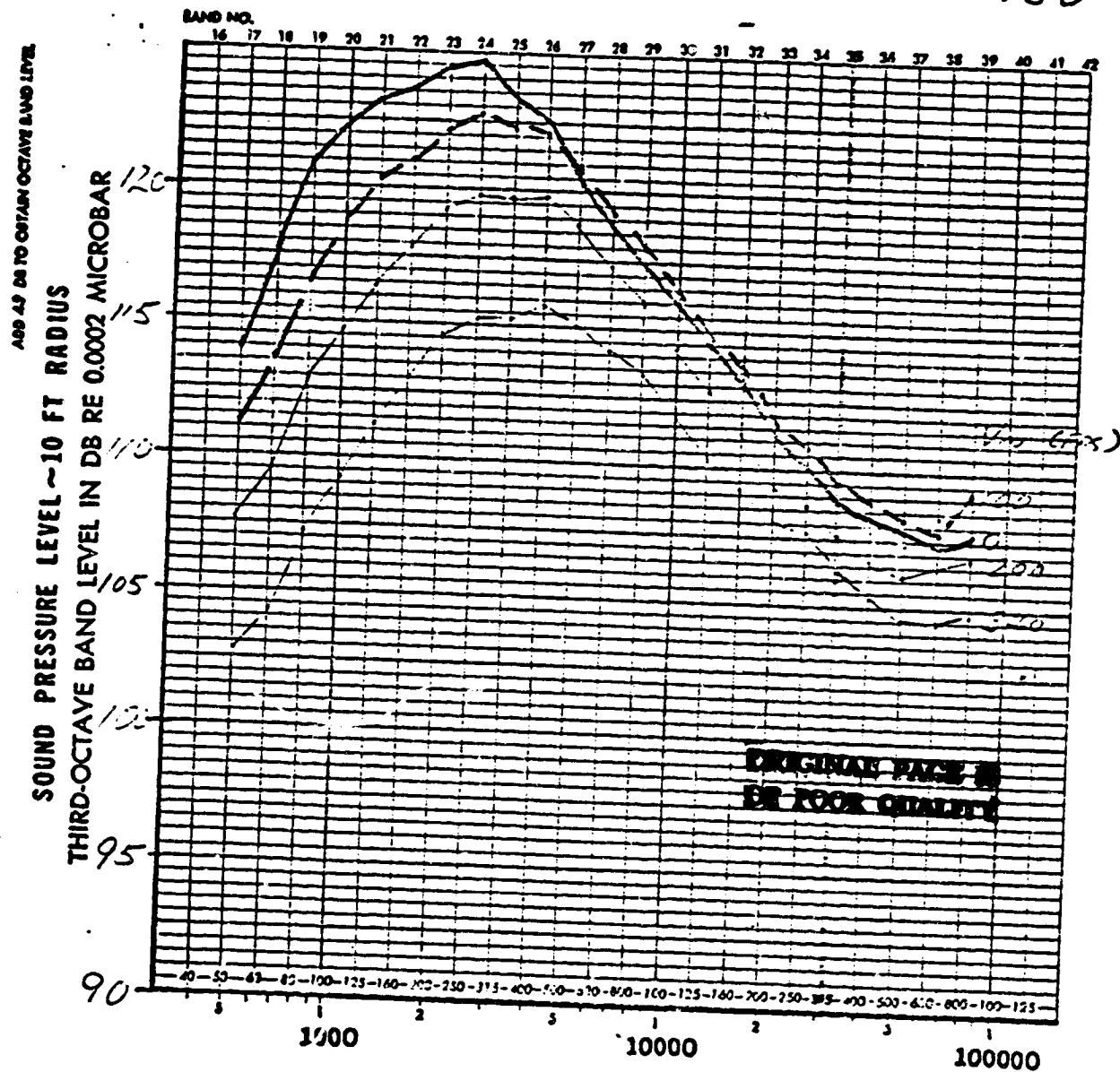
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3622	1905	600			0
----	3621					100
————	3620					200
----	3615					300

$$\frac{P_f}{P_{f=0}} = 3.2$$

RELATIVE VELOCITY EFFECT ON JET NOISE

CONVERGENT NOZZLE

$\theta = 150^\circ$



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3622	1905	600			0
---	3621					100
—	3620					200
---	3615					500

$$\frac{P_r}{P_{amb}} = 3.2$$

RELATIVE VELOCITY EFFECT ON JET NOISE

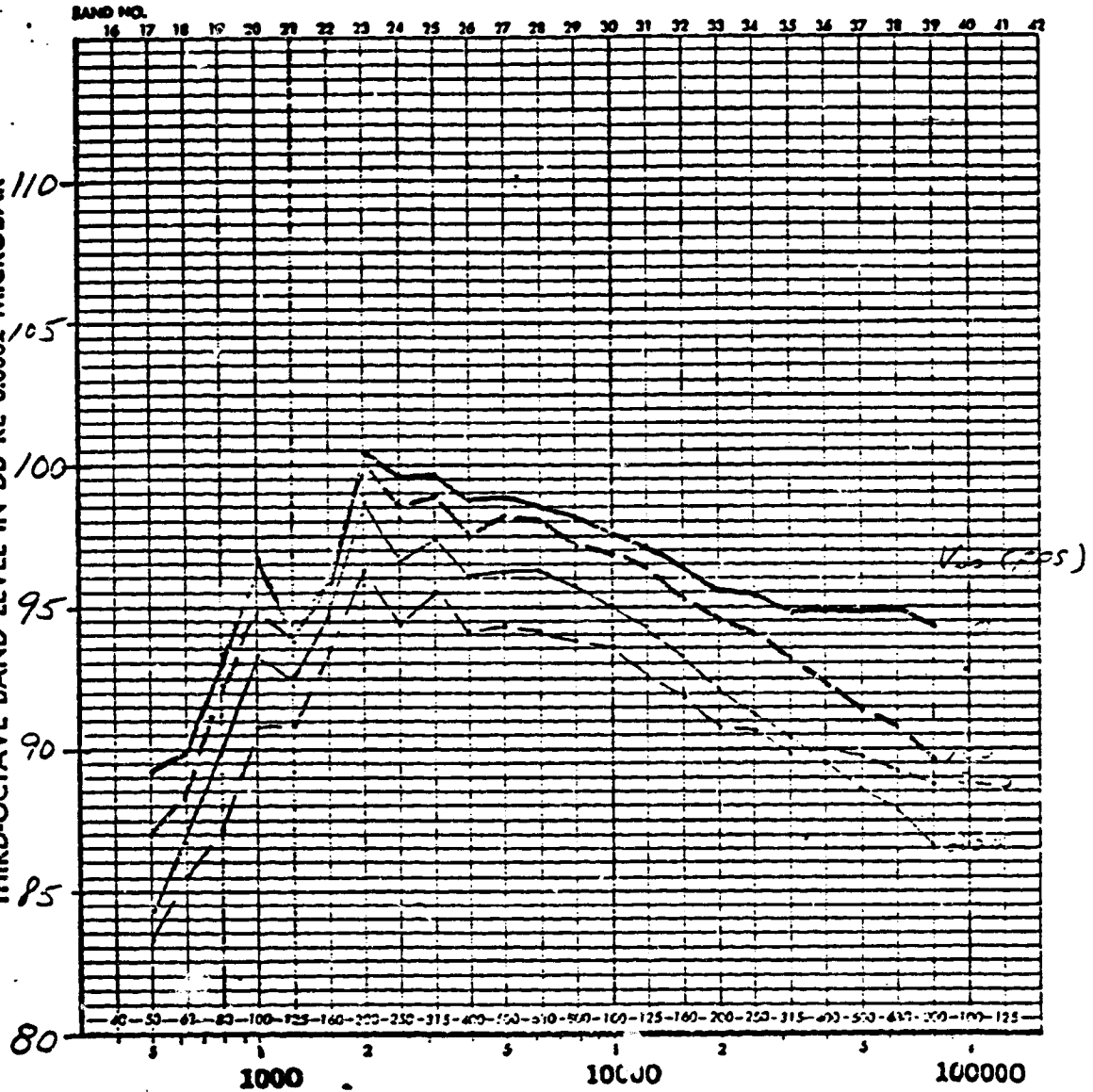
CONVERGENT NOZZLE

$\theta = 90^\circ$

ADD 4.5 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3631	1535	800			0
-----	3632					100
————	3639					200
-----	3648					340

$$\frac{P_f}{P_{f=0}} = 1.8$$

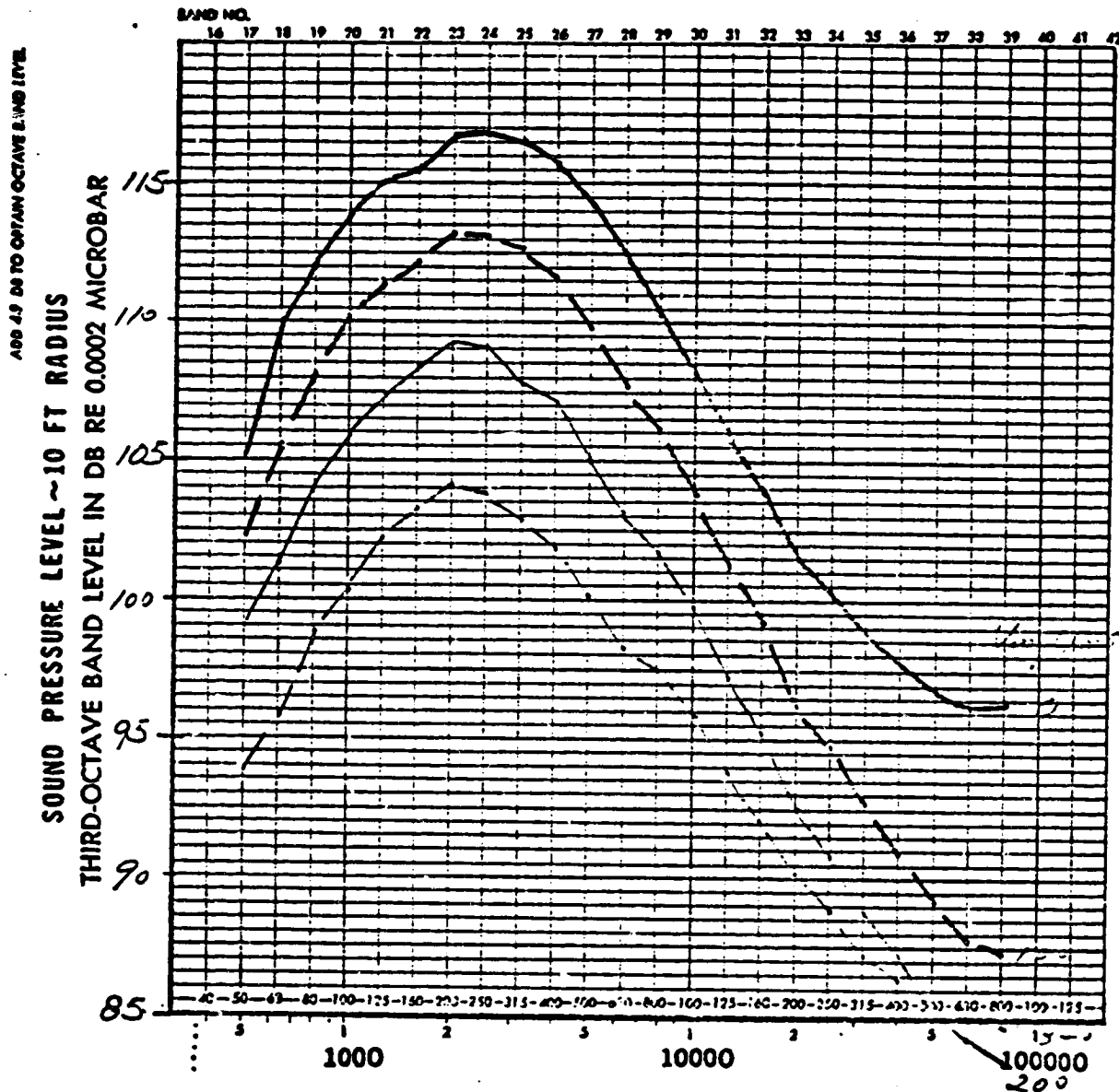
C-5

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RELATIVE VELOCITY EFFECT ON JET NOISE

CONVERGENT NOZZLE

$\theta = 150^\circ$



FREQUENCY IN HERTZ

	RUN NO.	V_D (fps)	T_D °F	V_f (fps)	T_f °F	V_∞ (fps)
—————	3631	1535	800	/	/	0
- - - - -	3630					100
—————	3629					200
- - - - -	3618					340

$$\frac{P_f}{P_D} = 1.8$$

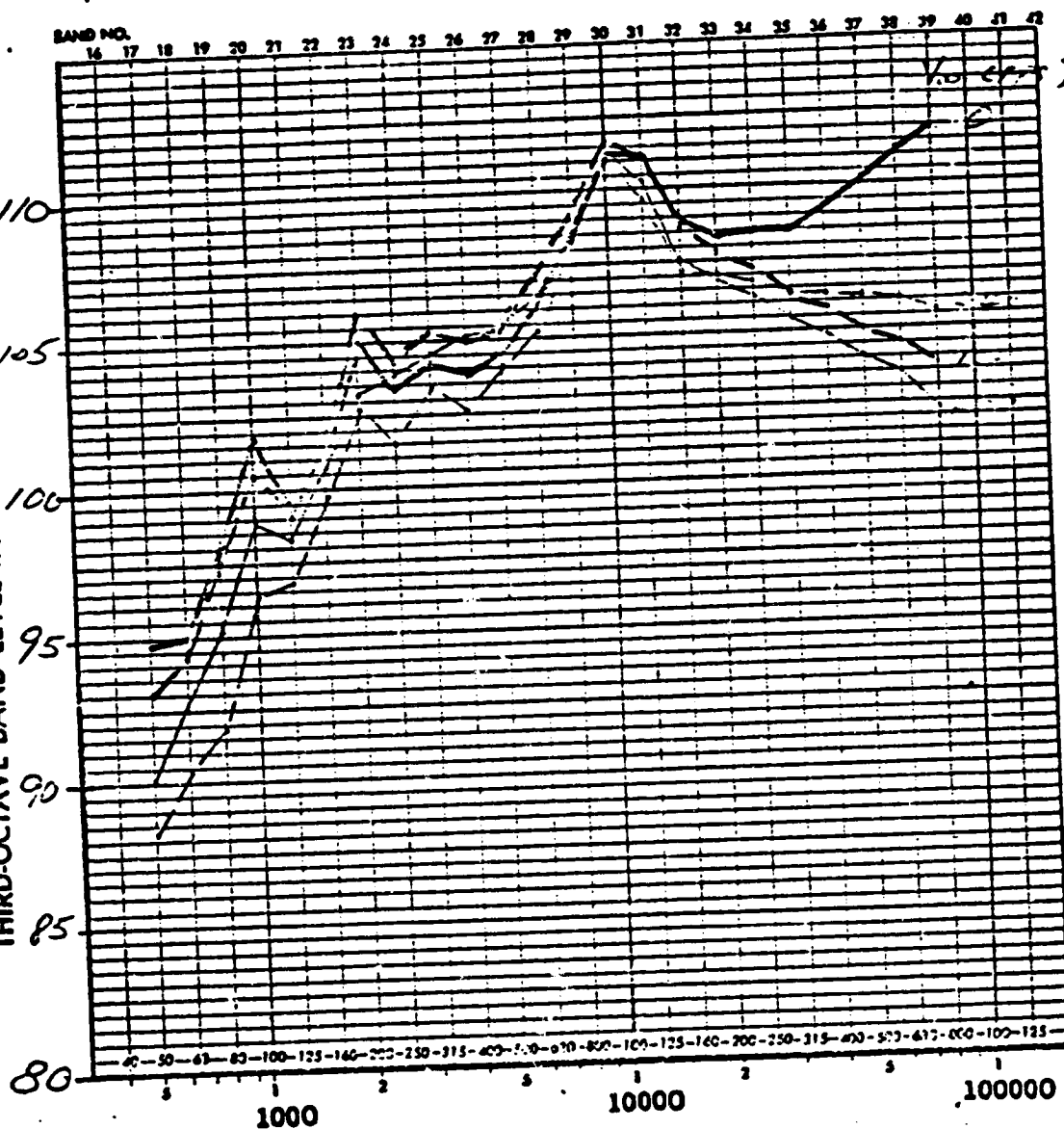
RELATIVE VELOCITY EFFECT ON JET NOISE

CONVERGENT NOZZLE

$\theta = 90^\circ$

ADD 49 DB TO OBTAIN OCTAVE B AND LVL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS
THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



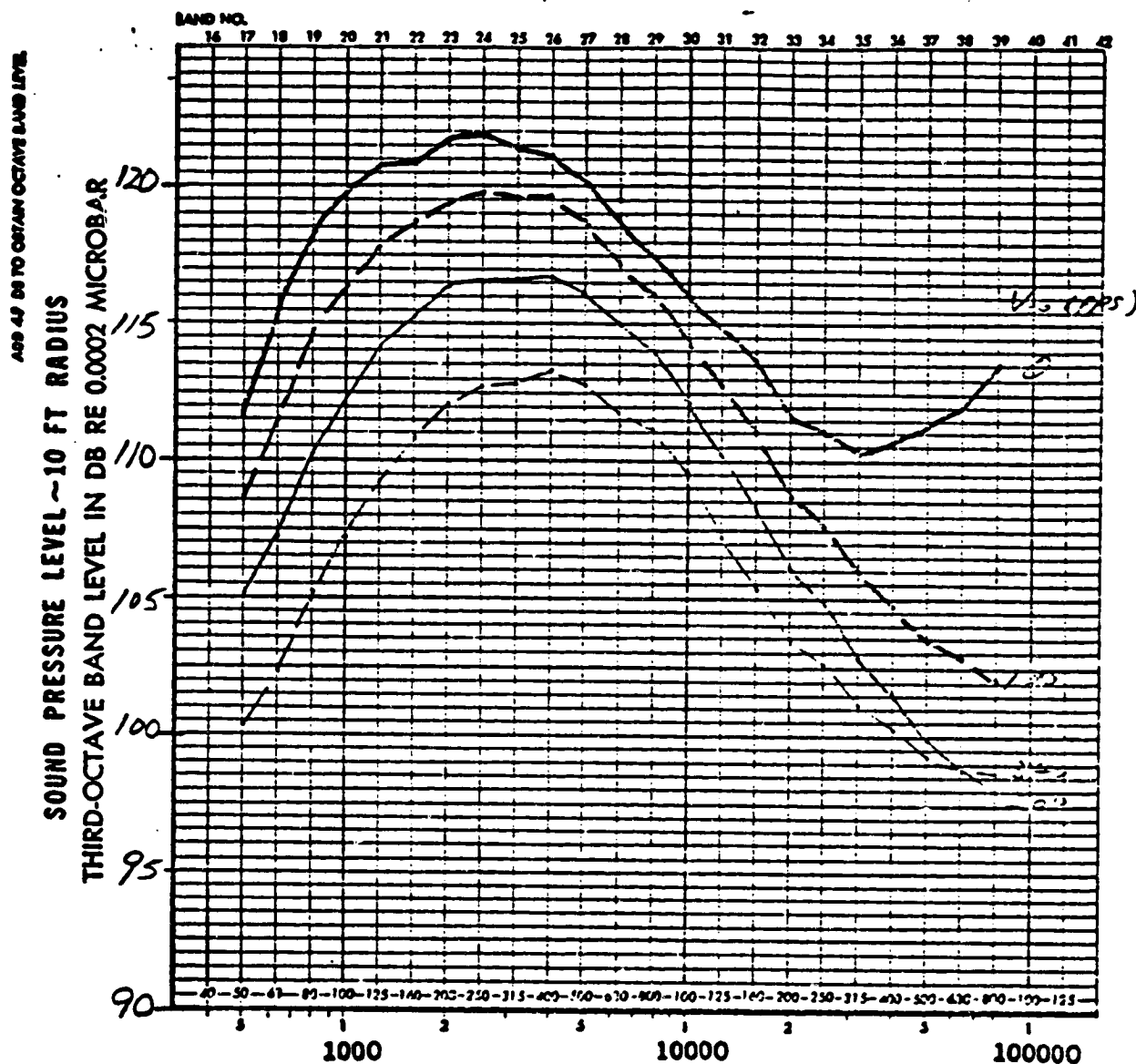
FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—————	3628	1875	800			0
— — — —	3627	↓	↓			100
—————	3626	↓	↓			200
— — — —	3617	↓	↓			340

$$\frac{P_e}{P_{amb}} = 2.5$$

RELATIVE VELOCITY EFFECT ON JET NOISE

CONVERGENT NOZZLES $\theta = 150^\circ$



	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3629	1875	800			0
— — —	3627	↓	↓			100
————	3626					200
— — —	3617	↓	↓			340

$\frac{P}{R} = 2.5$

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C-8 OF POOR QUALITY

RELATIVE VELOCITY EFFECT ON JET NOISE

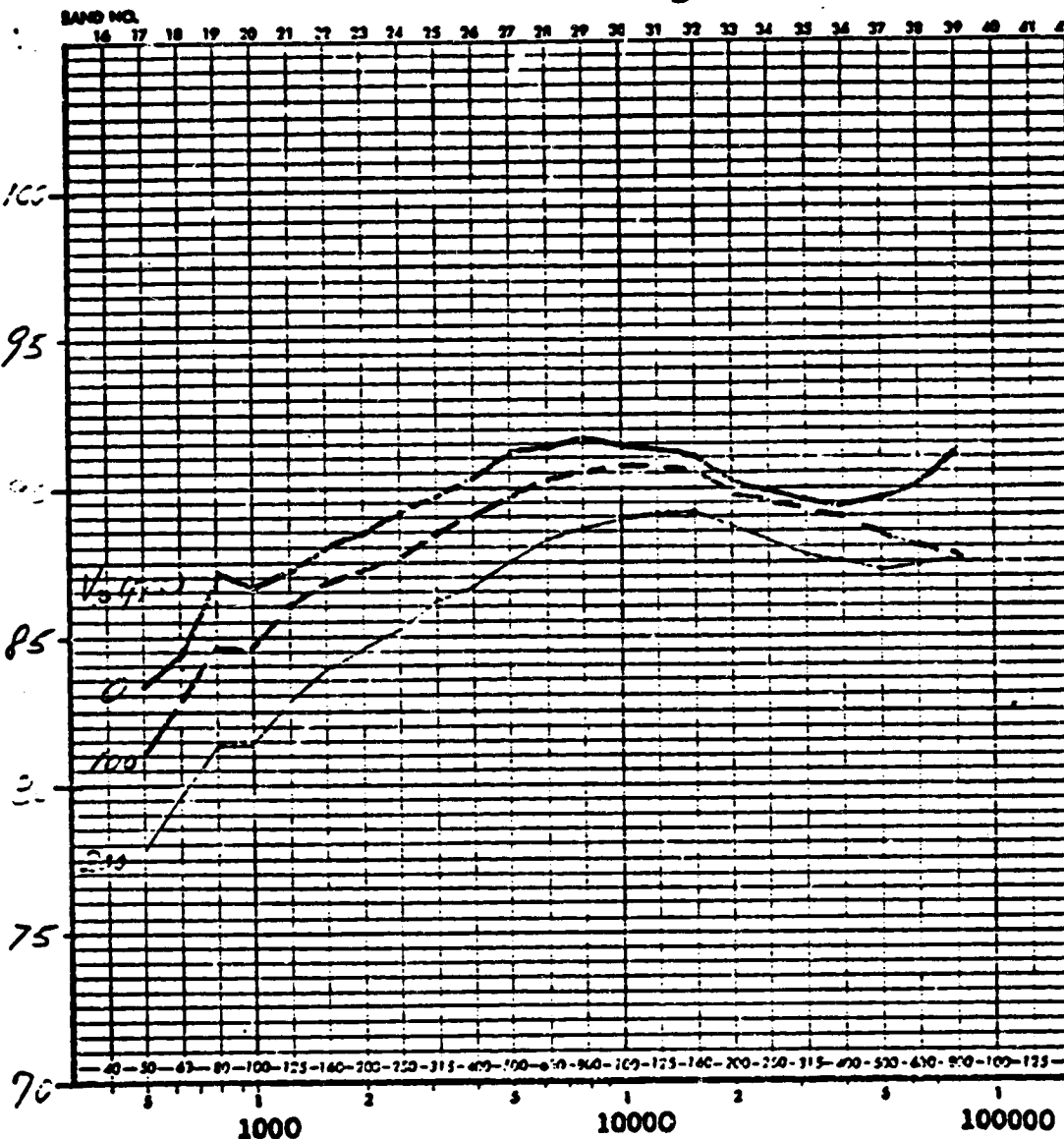
0.75 AR ANNULAR NOZZLE

$\theta = 90^\circ$

ADD 45 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



ORIGINAL DATA
 FREQUENCY IN HERTZ OF 2008 QUALITY

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3346	990	250	1405	600	0
- - -	3347	↓	↓	↓	↓	100
—	3348	↓	↓	↓	↓	200

$$\frac{P_{LP}}{P_{AMB}} = 1.53$$

$$\frac{P_{HS}}{P_{AMB}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

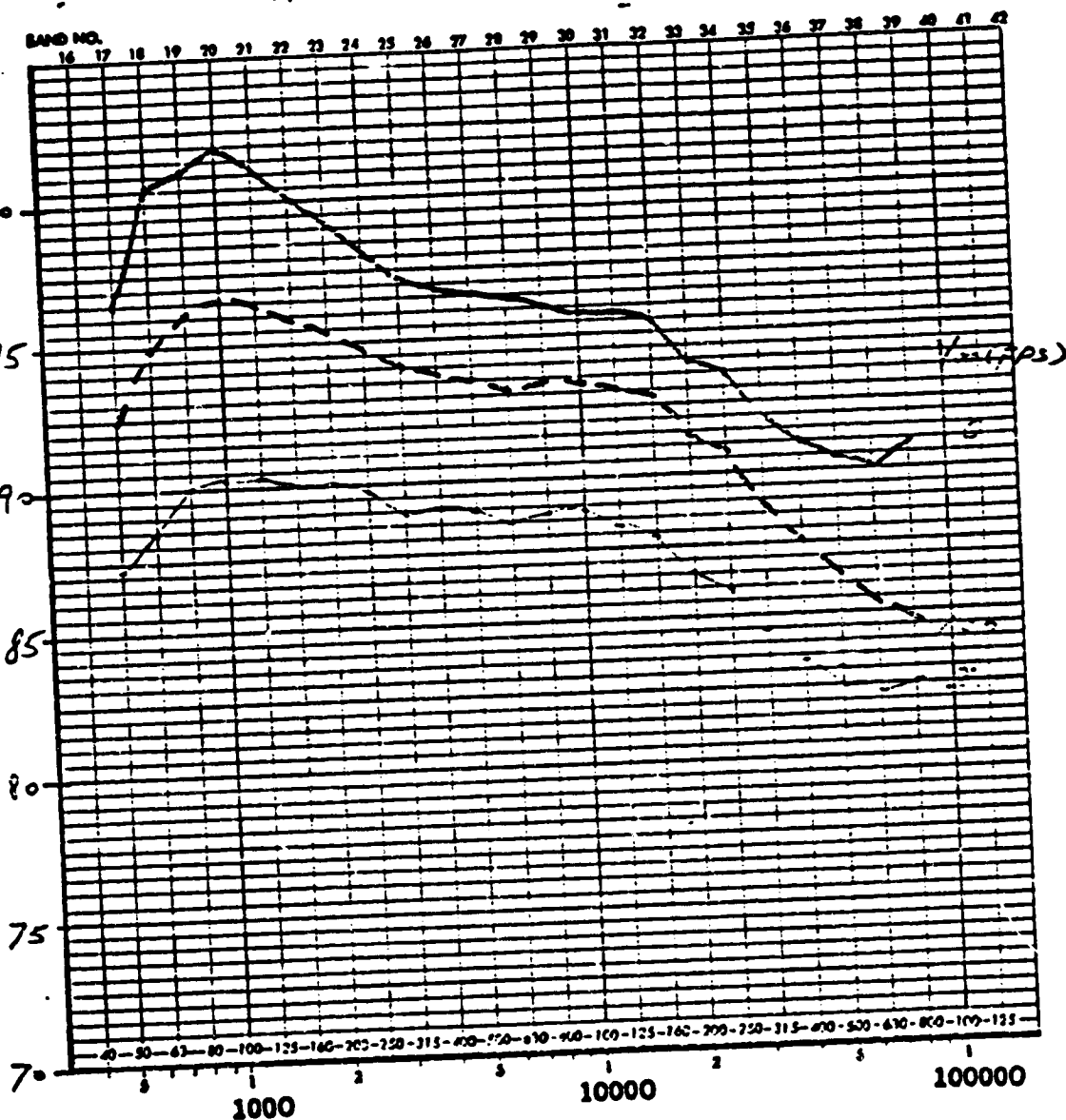
0.75 AR CONNULAR NOZZLE

$\theta = 150^\circ$

ADD 4.5 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3346	990	250	1405	600	0
- - -	3347	↓	↓	↓	↓	100
- . -	3348	↓	↓	↓	↓	200

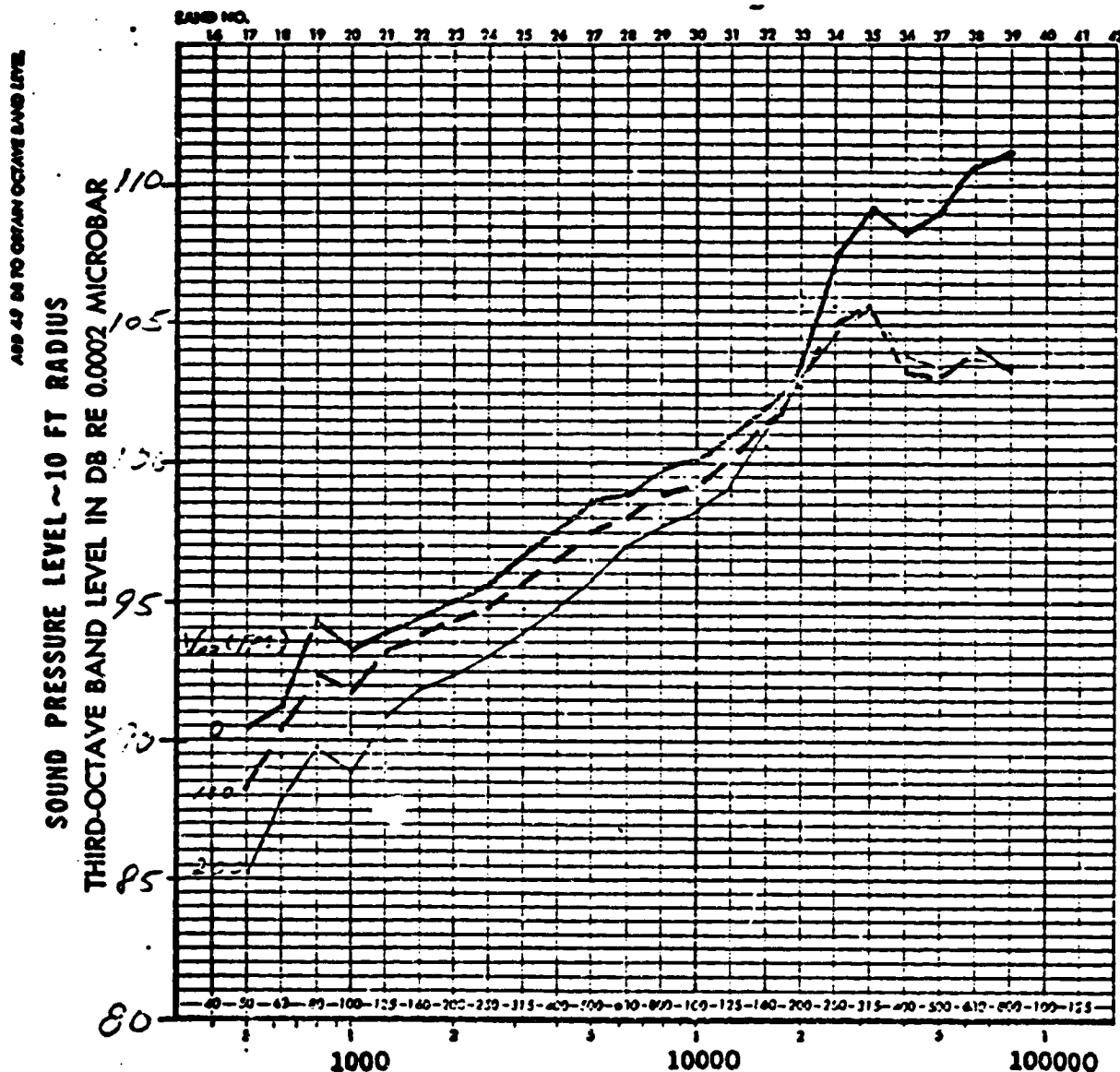
$$\frac{P_{100}}{P_{0.0}} = 1.53$$

$$\frac{P_{100}}{P_{0.0}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR CONNULAR NOZZLE

$\theta = 90^\circ$



FREQUENCY IN HERTZ

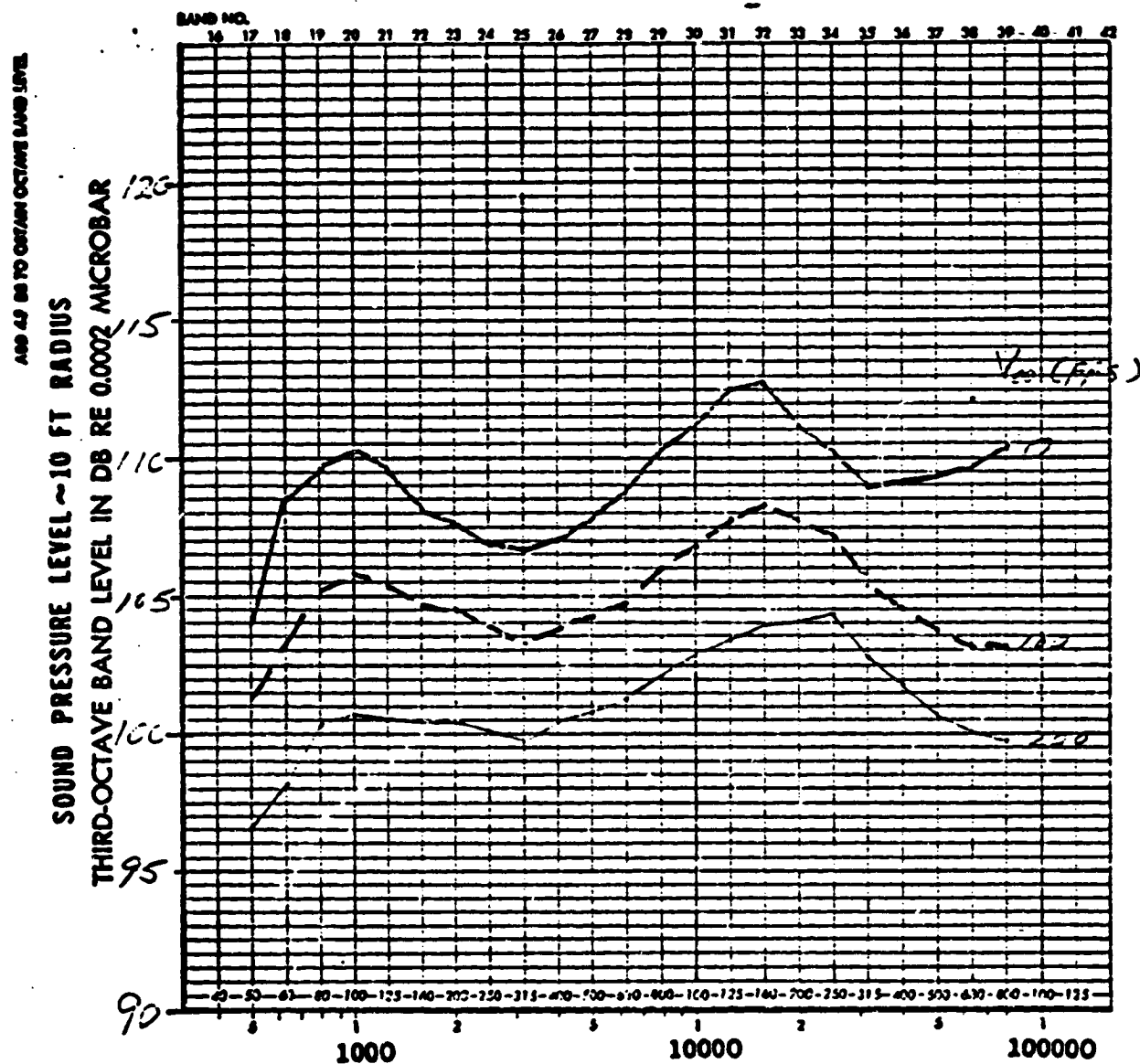
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3140	990	250	1905	600	0
- - -	3141	↓	↓	↓	↓	100
—	3142	↓	↓	↓	↓	200

$$\frac{P_{31}}{P_{100}} = 1.53$$

$$\frac{P_{31}}{P_{200}} = 3.2$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR ANNULAR NOZZLE $\theta = 150^\circ$



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_{∞} (fps)
————	3340	990	250	1905	600	0
-----	3341	↓	↓	↓	↓	100
————	3342	↓	↓	↓	↓	200

$\frac{P_{0.5}}{P_{amb}} = 1.53$

$\frac{P_{0.5}}{P_{amb}} = 3.2$

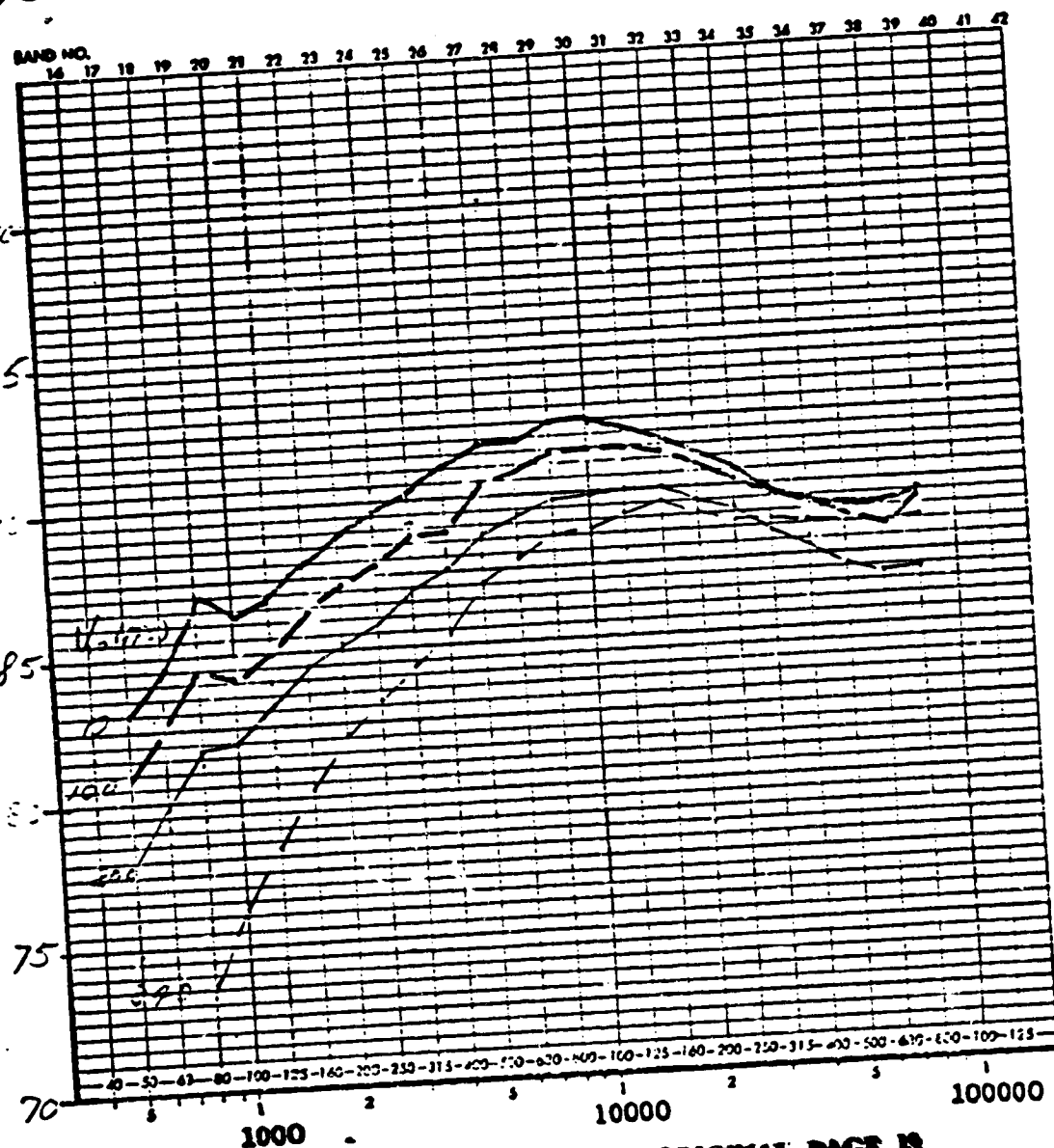
RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR CANNULAR NOZZLE

$\theta = 90^\circ$

ADD 49 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS
THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



ORIGINAL PAGE IS
FREQUENCY IN. HZ. OF POOR QUALITY

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3365	990	250	1535	800	0
---	3366	↓	↓	↓	↓	100
—	3367	↓	↓	↓	↓	200
----	3374	↓	↓	↓	↓	300

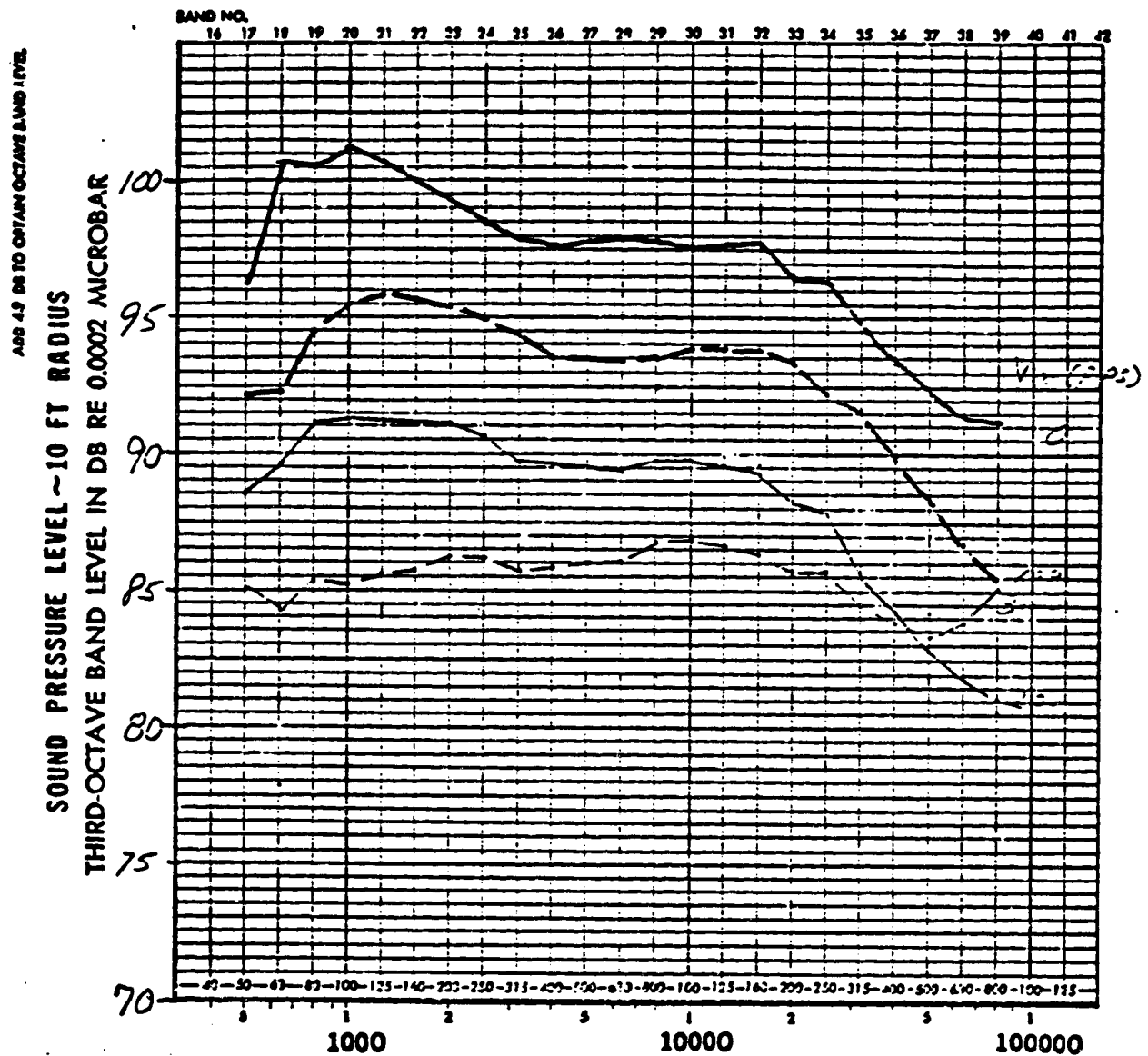
$$\frac{P_{3365}}{P_{3366}} = 1.53$$

$$\frac{P_{3365}}{P_{3366}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR COANNULAR NOZZLE

$\theta = 150^\circ$



	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3365	990	250	1535	800	0
---	3366					100
—	3367					200
---	3374					300

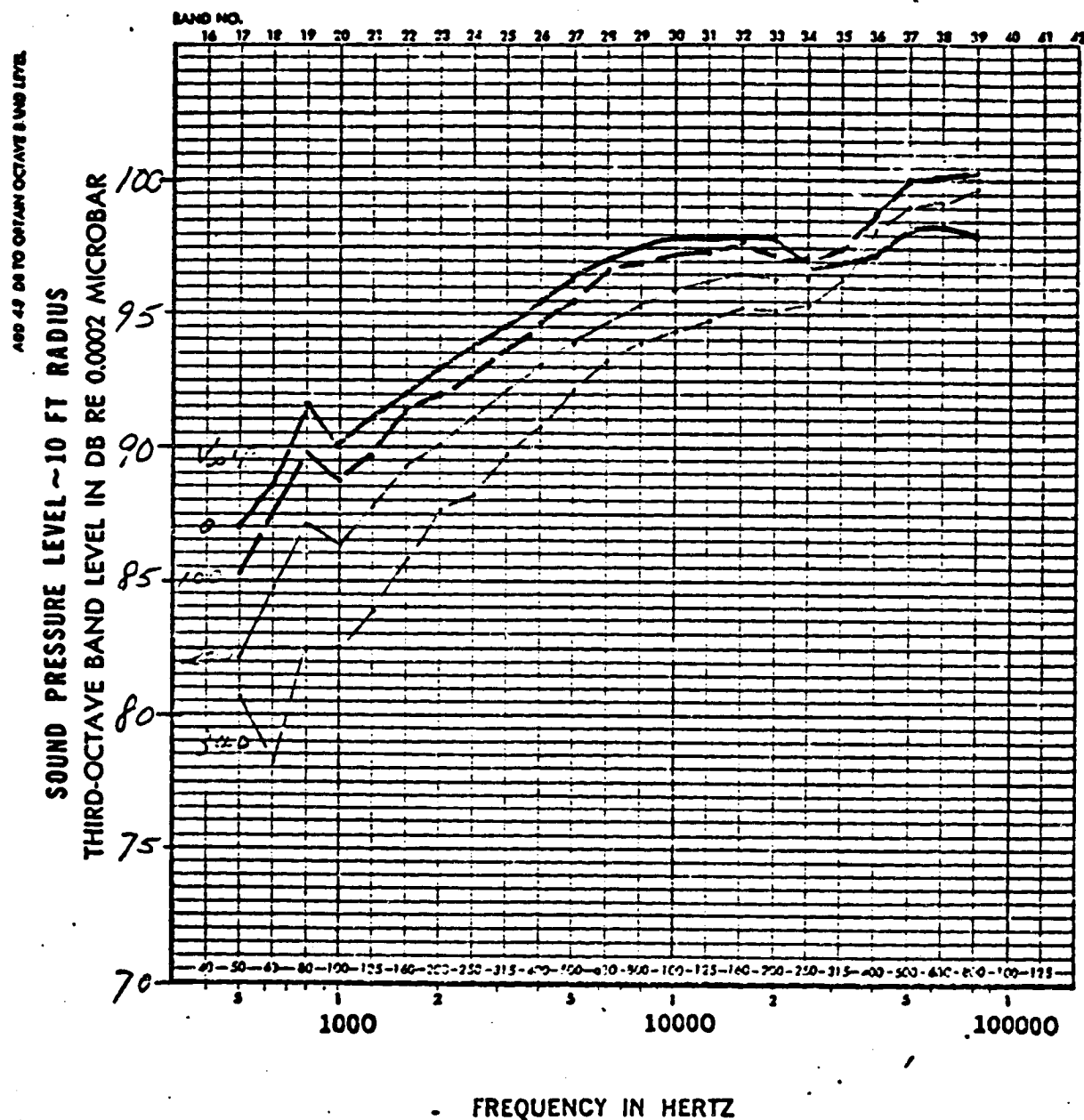
$$\frac{P_{11}}{P_{amb}} = 1.53$$

$$\frac{P_{11}}{P_{amb}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR COANNULAR NOZZLE

$\theta = 90^\circ$



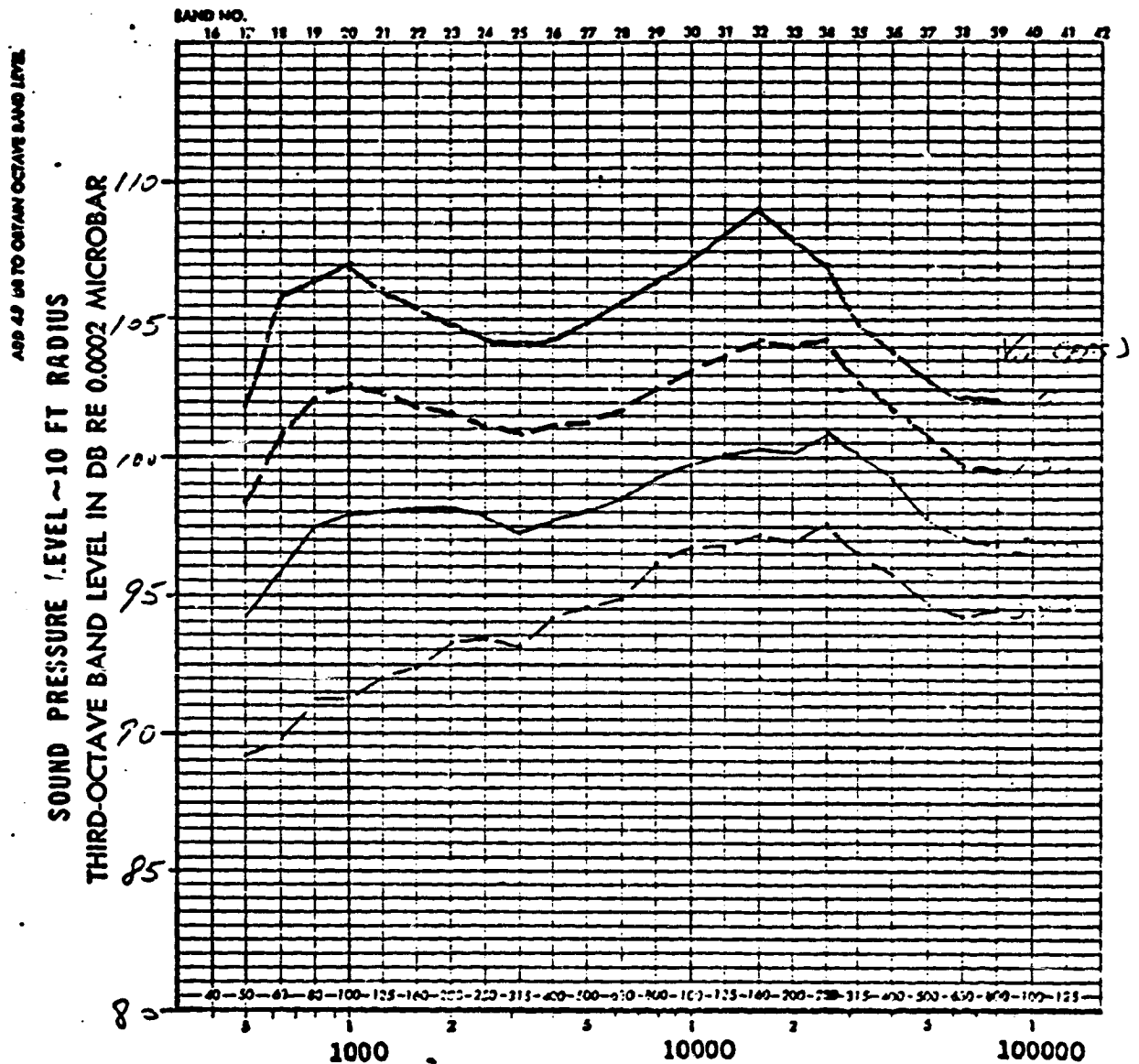
	RUN NO.	V_p (fps)	T_p °F	V_j (fps)	T_j °F	V_∞ (fps)
—	3364	990	250	1875	800	0
---	3363					100
—	3362					200
---	3373					340
—	3372	↓	↓	↓	↓	425

$$\frac{P_{3P}}{P_{n=6}} = 1.53$$

$$\frac{P_{3P}}{P_{n=6}} = 2.5$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR COANNULAR NOZZLE $\theta = 150^\circ$



FREQUENCY IN HERTZ

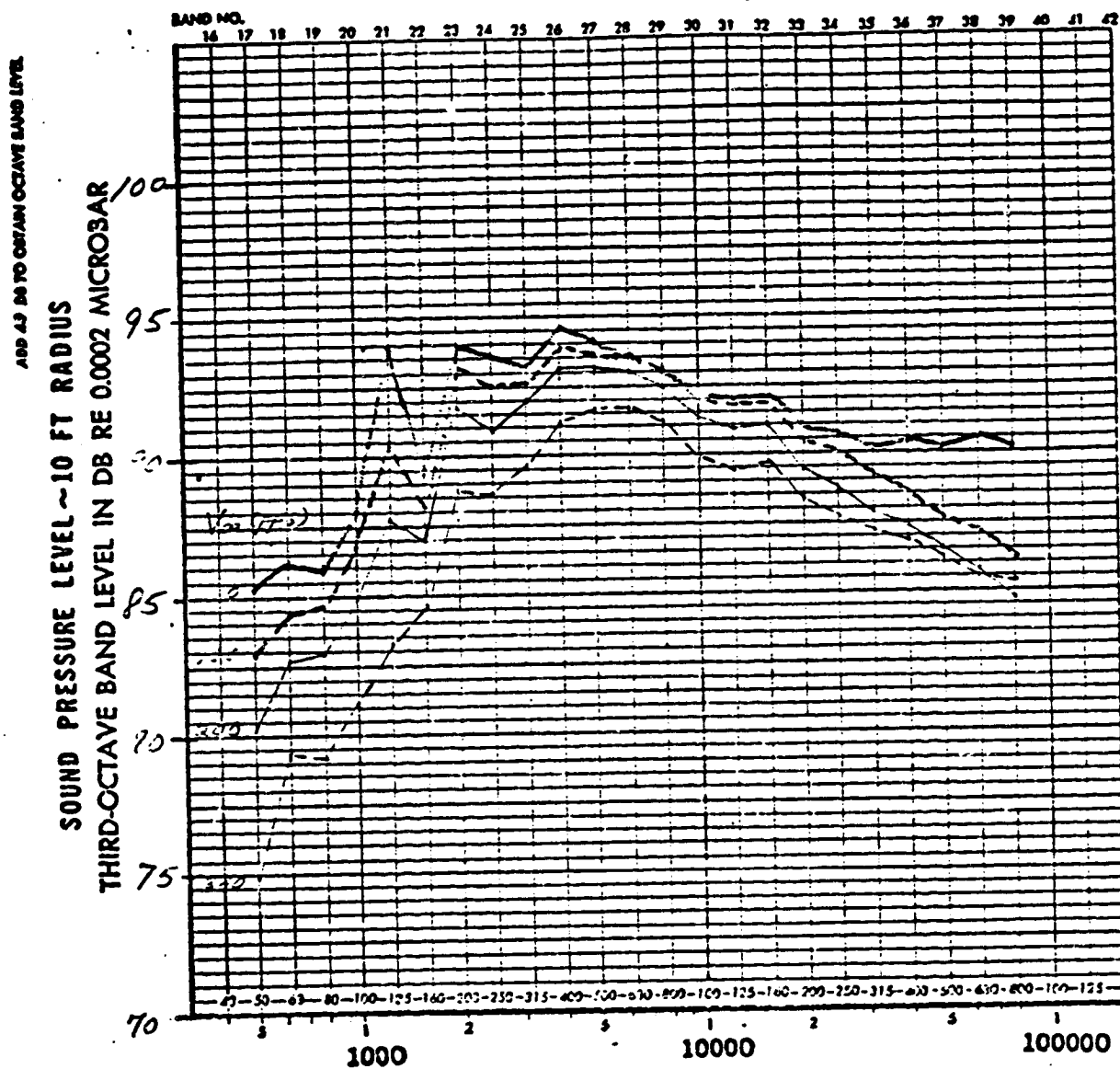
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	2364	990	250	1975	800	0
----	2363	↓	↓	↓	↓	100
—	3362	↓	↓	↓	↓	200
----	3375	↓	↓	↓	↓	300

$$\frac{P_{jet}}{P_{amb}} = 1.53$$

$$\frac{P_{jet}}{P_{amb}} = 2.5$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR COANNULAR NOZZLE WITH EJECTOR $\theta = 90^\circ$



FREQUENCY IN. HERTZ

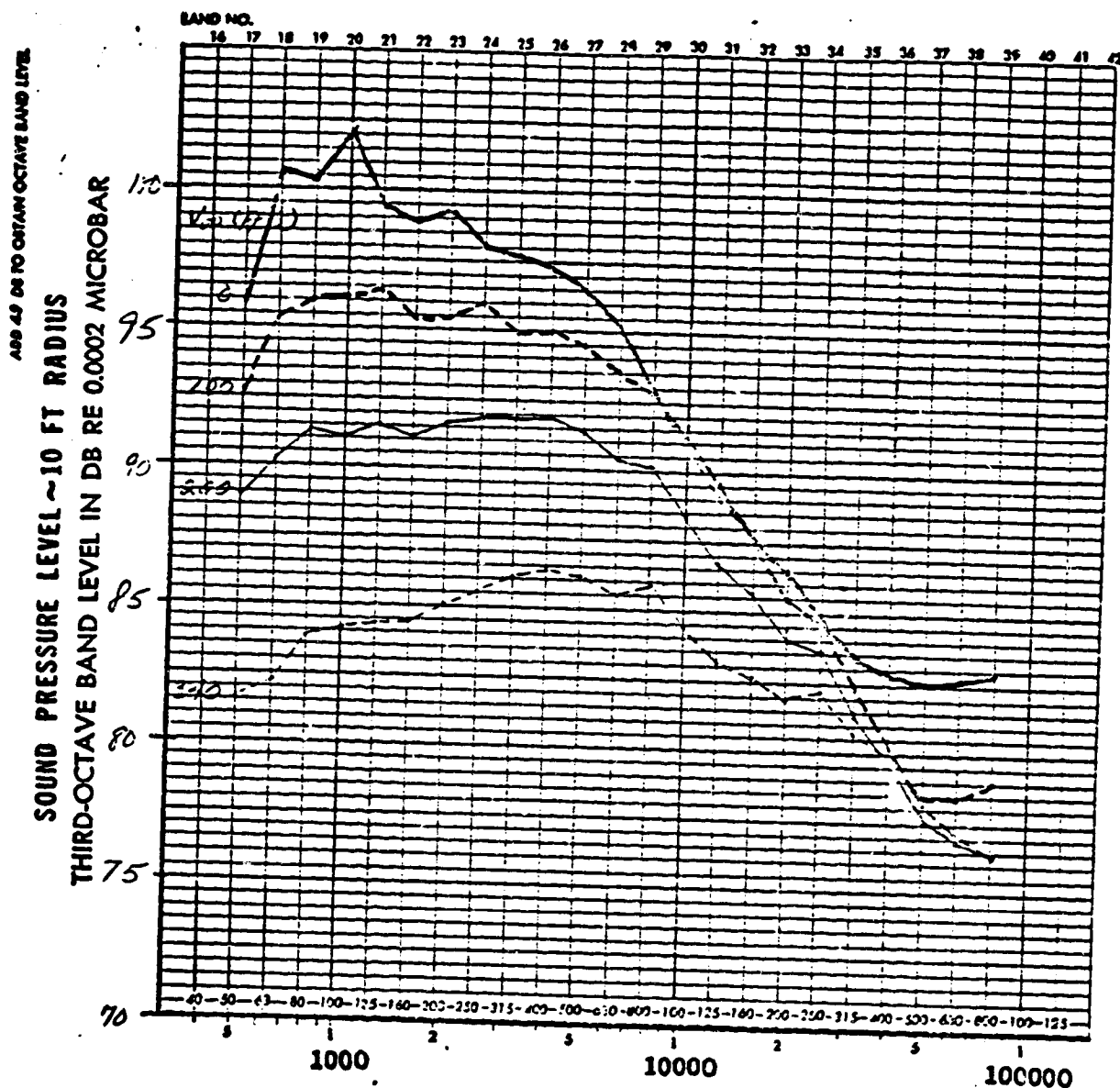
	RUN NO.	V_p (fps)	T_p °F	V_j (fps)	T_j °F	V_∞ (fps)
————	3526	990	250	1405	600	5
-----	3527	↓	↓	↓	↓	100
————	3528	↓	↓	↓	↓	500
-----	3554	↓	↓	↓	↓	340

$$\frac{P_{jet}}{P_{amb}} = 1.55$$

$$\frac{P_{jet}}{P_{amb}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR ANNULAR NOZZLE WITH EJECTOR $\theta = 150^\circ$



FREQUENCY IN HERTZ

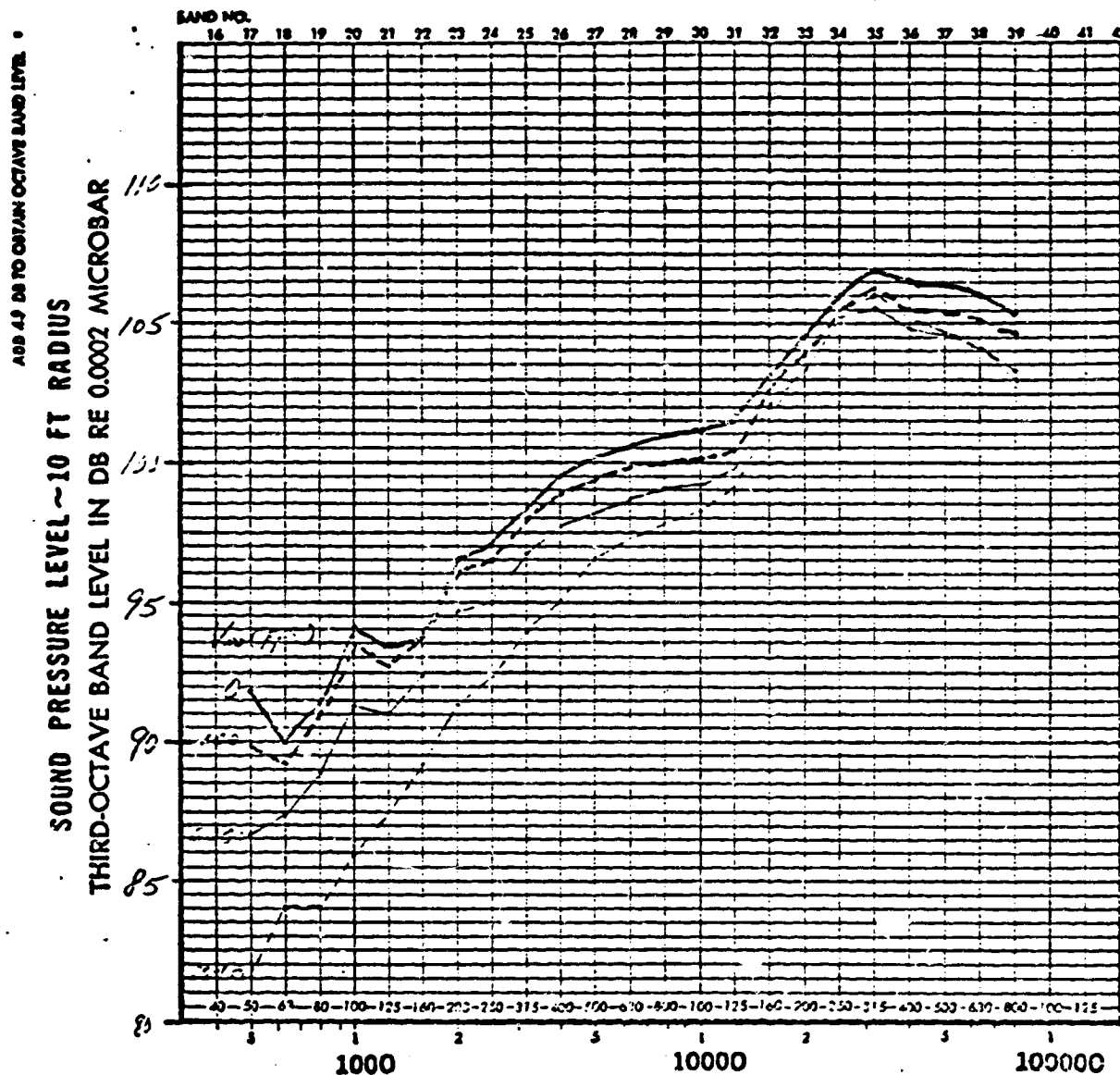
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—————	3530	990	250	1405	600	0
-----	3537					100
—————	3538					200
-----	3554	Y	Y	Y	Y	340

$$\frac{P_{p1}}{P_{amb}} = 1.53$$

$$\frac{P_{f1}}{P_{amb}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR COANNULAR NOZZLE WITH EJECTOR $\theta = 90^\circ$



FREQUENCY IN HERTZ

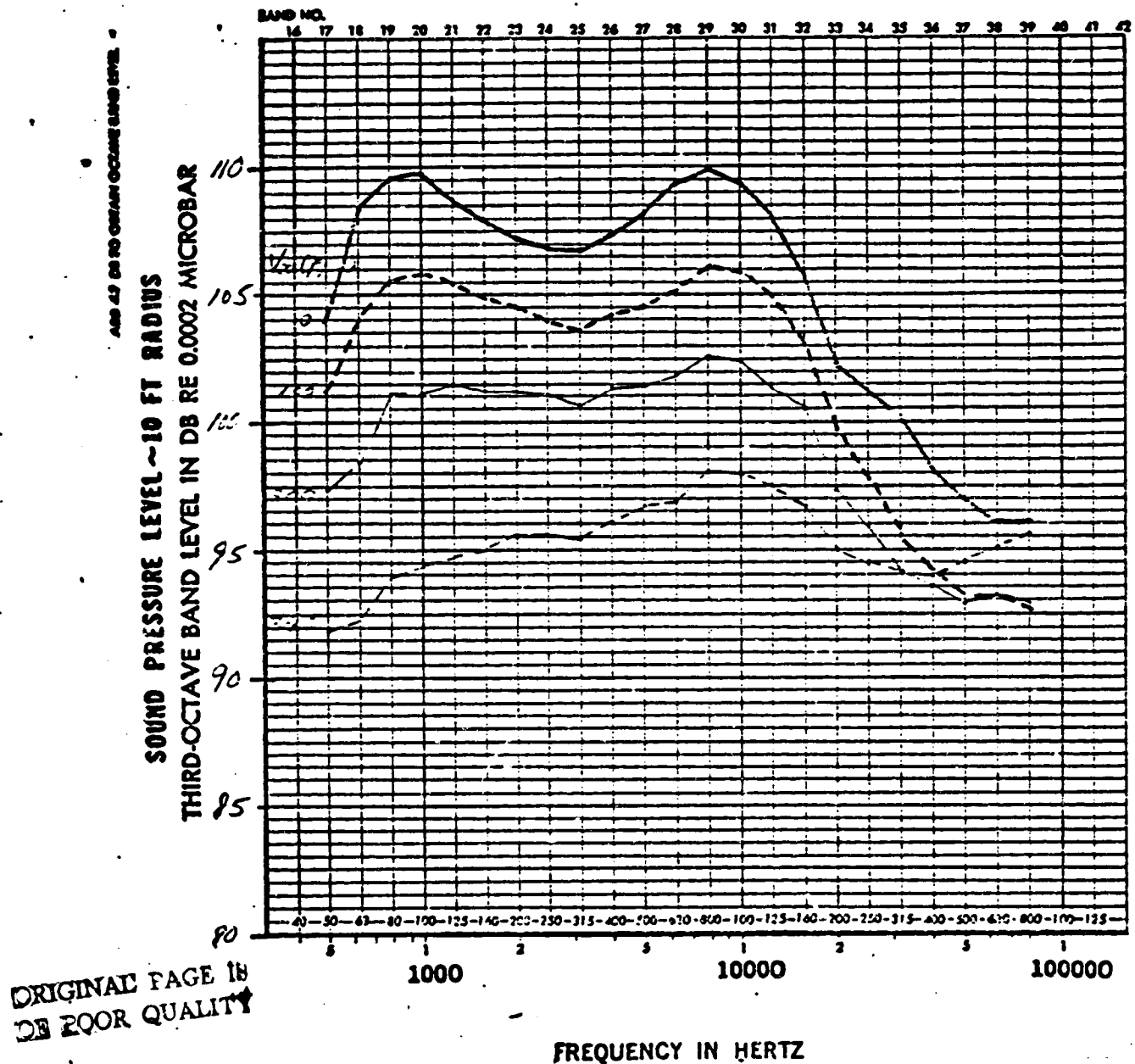
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3524	990	250	1905	600	0
-----	3523					100
————	3522					200
-----	3552	Y	Y	Y	Y	300

$$\frac{P_{1P}}{P_{0.6}} = 1.53$$

$$\frac{P_{1P}}{P_{0.6}} = 3.2$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR CANNULAR NOZZLE WITH EJECTOR $\theta = 150^\circ$



	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3524	990	250	1905	600	0
-----	3523	↓	↓	↓	↓	100
————	3522	↓	↓	↓	↓	200
-----	3552	↓	↓	↓	↓	300

$$\frac{P_{eP}}{P_{amb}} = 1.53$$

$$\frac{P_{eH}}{P_{amb}} = 3.2$$

RELATIVE VELOCITY EFFECT ON JET NOISE

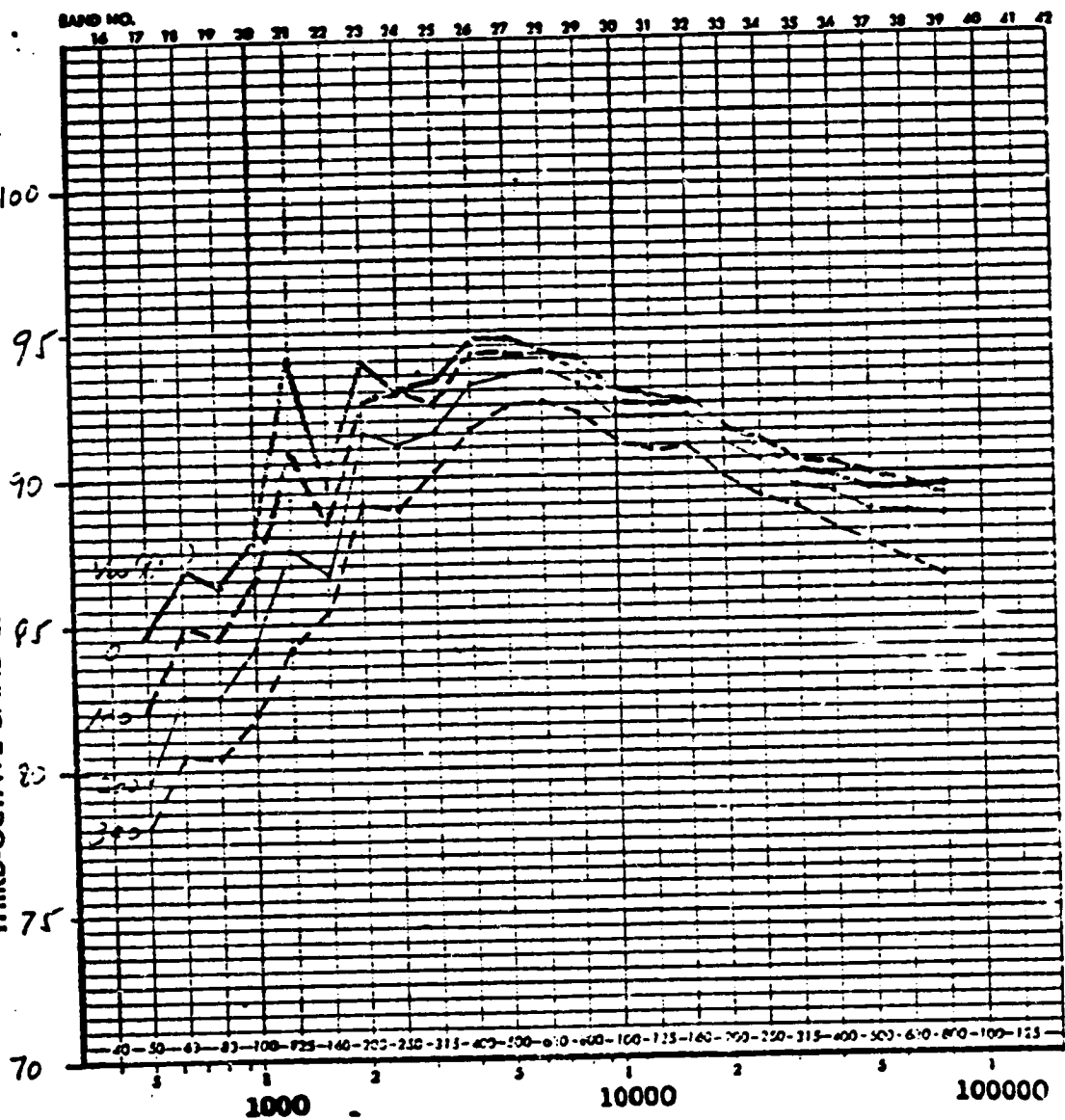
0.75 AR CONNULAR NOZZLE WITH EJECTOR

$\theta = 90^\circ$

ADD 4.5 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN. HERTZ

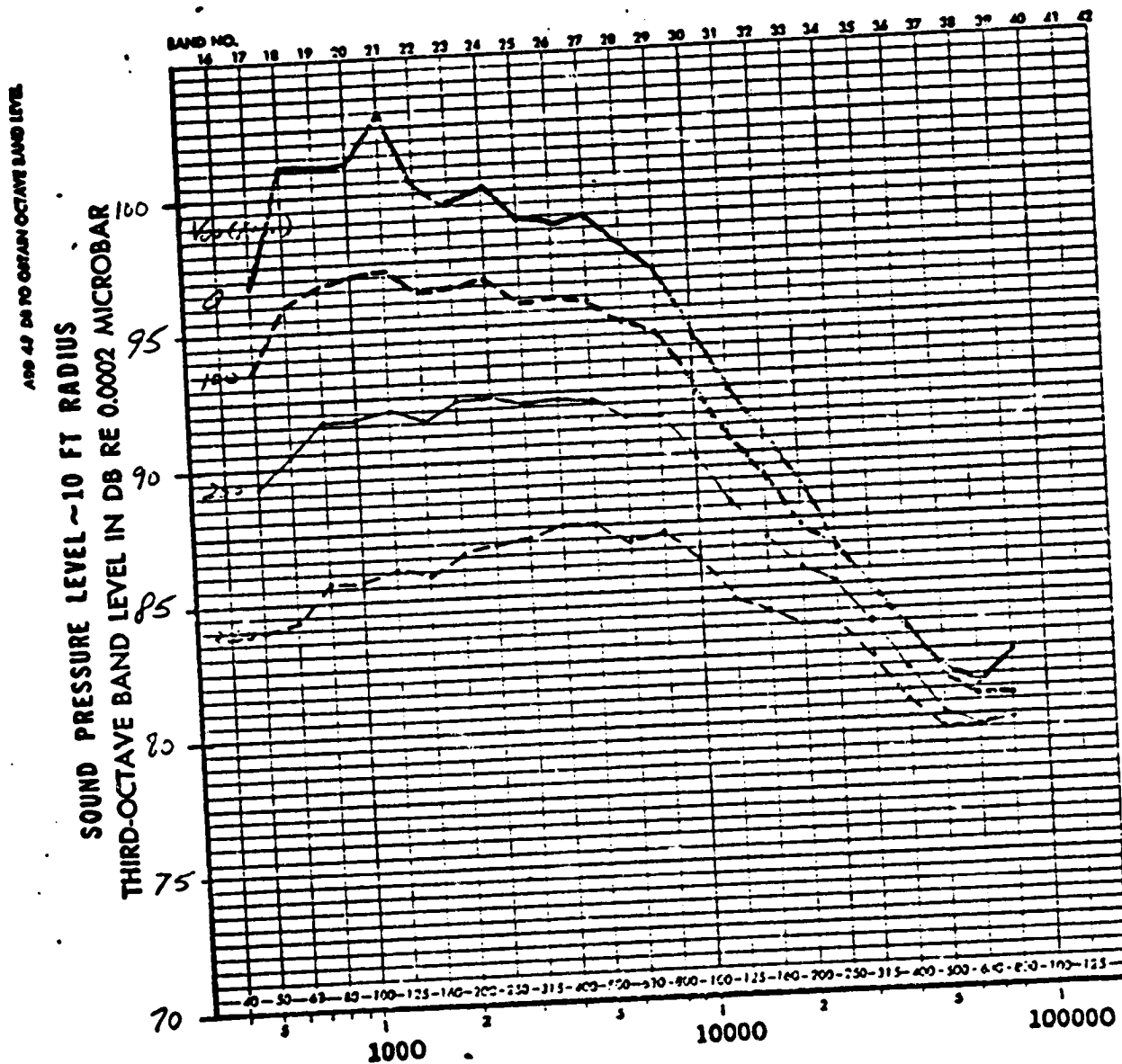
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3540	990	250	1535	800	0
-----	3541					100
————	3542					200
-----	3550	✓	✓	✓	✓	340

$$\frac{P_{jet}}{P_{amb}} = 1.53$$

$$\frac{P_{jet}}{P_{amb}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR CONICAL NOZZLE WITH EJECTOR $\theta = 150^\circ$



FREQUENCY IN. HERTZ

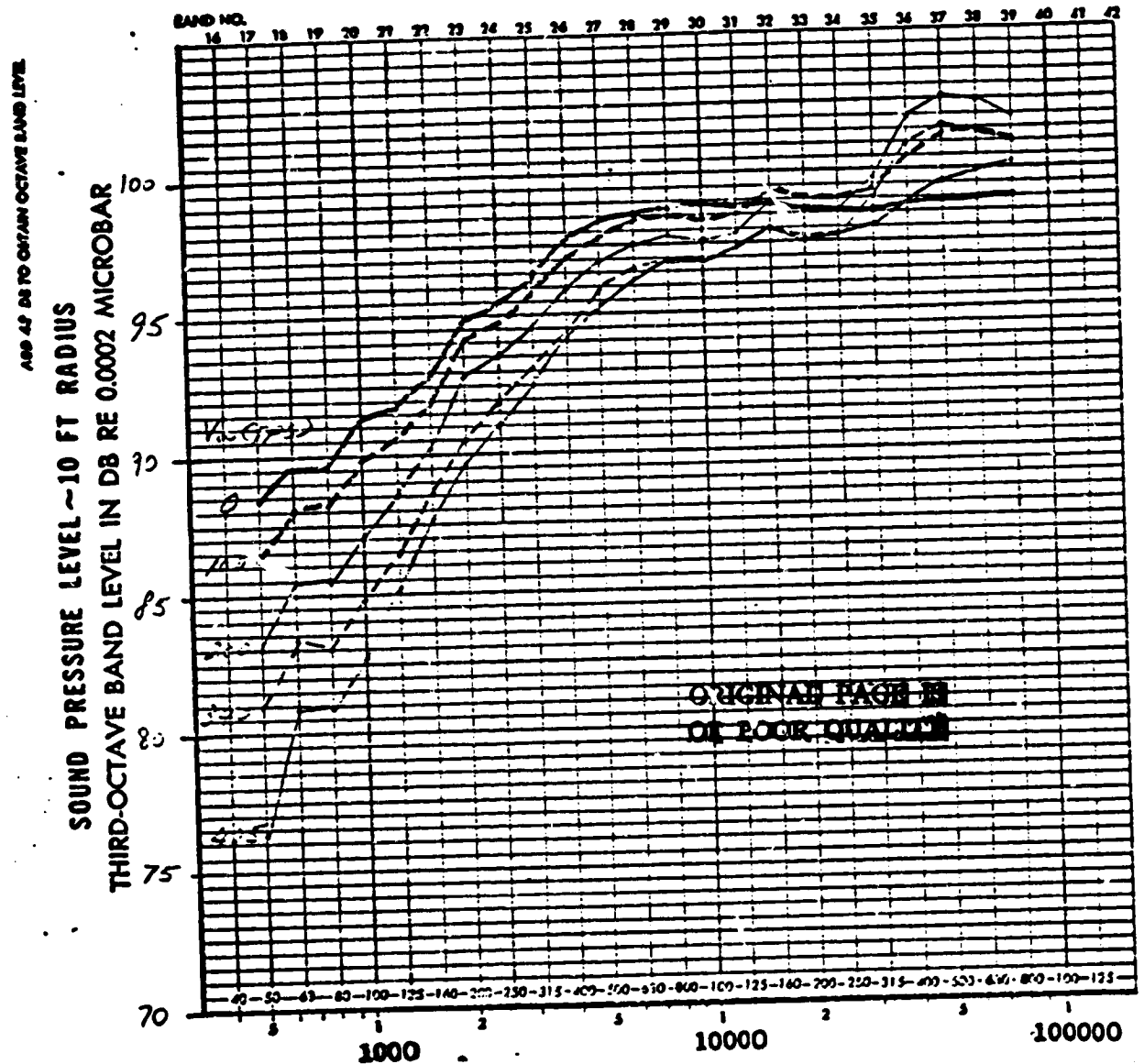
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3500	990	250	1535	800	0
-----	3501	↓	↓	↓	↓	100
————	3512	↓	↓	↓	↓	200
-----	3550	↓	↓	↓	↓	300

$$\frac{P_{15}}{P_{10}} = 1.53$$

$$\frac{P_{15}}{P_{10}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR, CONNULAR NOZZLE WITH EJECTOR $\theta = 90^\circ$



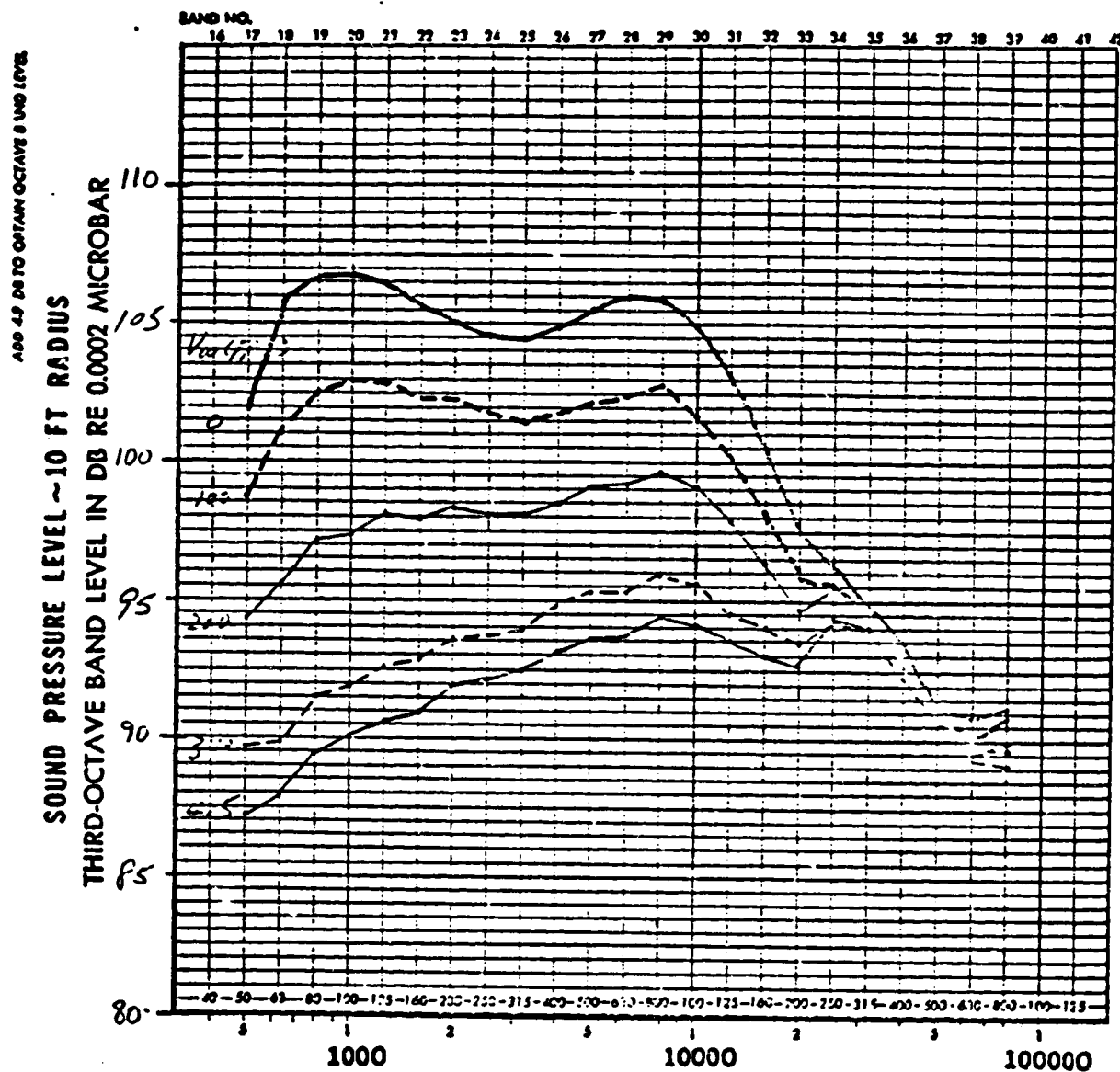
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3539	990	250	1875	800	0
-----	3538					100
————	3537					200
-----	3549					300
————	3548	Y	Y	Y	Y	425

$$\frac{P_{e1}}{P_{e0}} = 1.53$$

$$\frac{P_{e1}}{P_{e0}} = 2.5$$

RELATIVE VELOCITY EFFECT ON JET NOISE

0.75 AR COANNULAR NOZZLE WITH EJECTOR $\theta = 150^\circ$



	RUN NO.	V_p (fps)	T_p °F	V_e (fps)	T_e °F	V_∞ (fps)
————	3539	990	250	1875	800	0
-----	3538					100
————	3537					200
-----	3529					300
————	3528					425

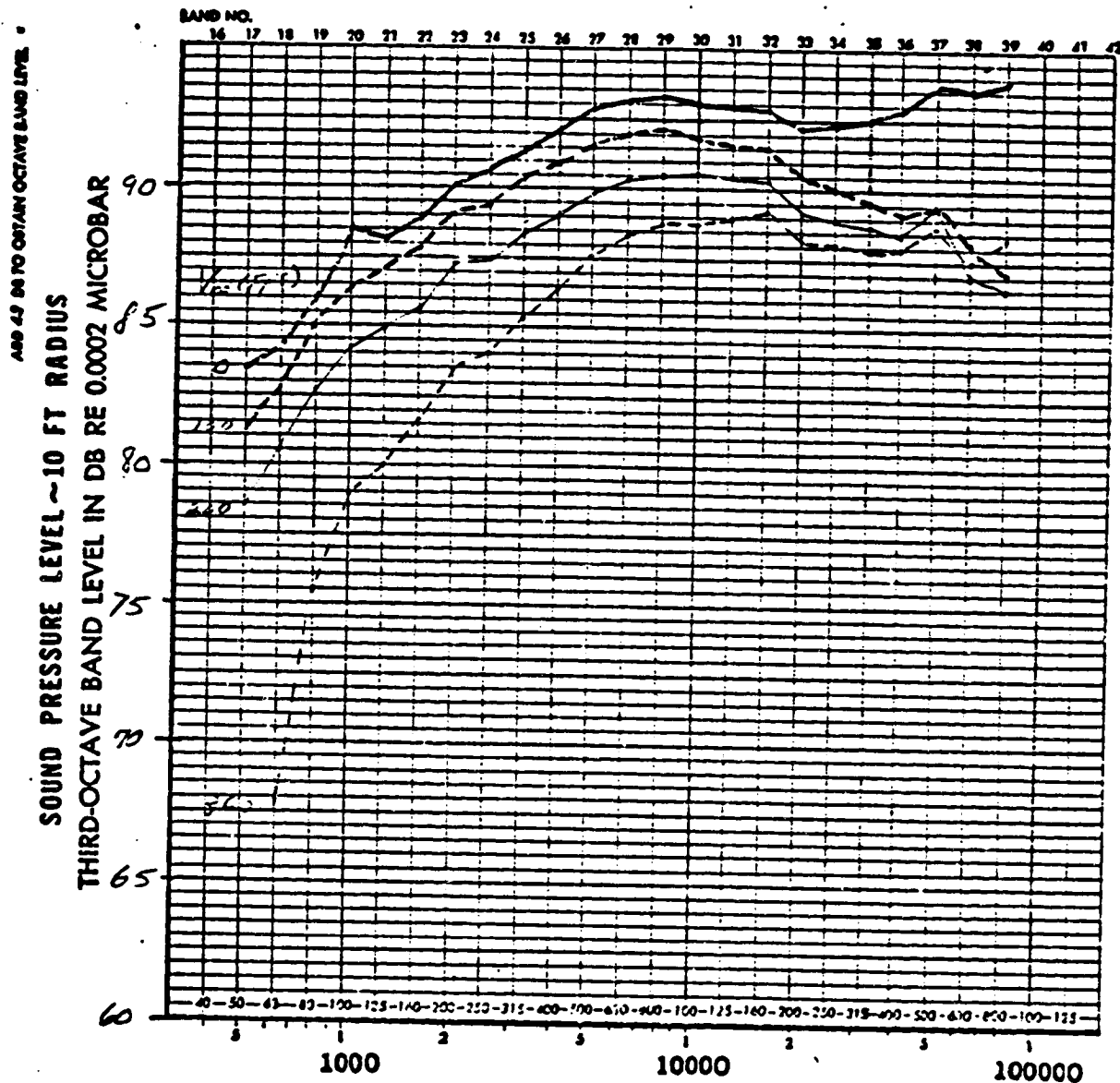
$$\frac{P_{e,p}}{P_{e,0}} = 1.53$$

$$\frac{P_{e,f}}{P_{e,0}} = 2.5$$

RELATIVE VELOCITY EFFECT ON JET NOISE

1.2 AR COANNULAR NOZZLE

$\theta = 90^\circ$



	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—	3432	990	250	1405	600	0
---	3431					100
—	3430					200
----	3416					300

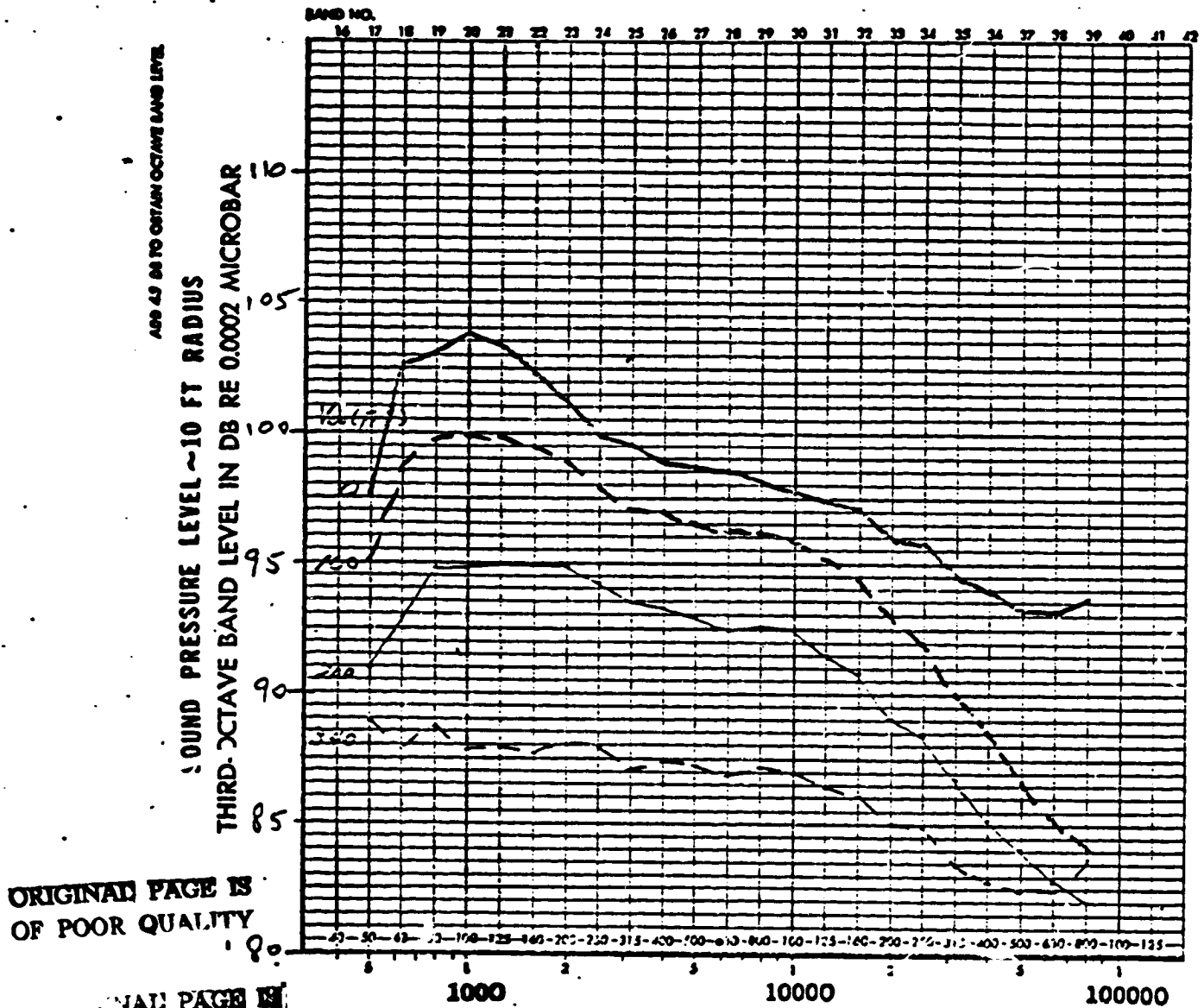
$$\frac{P_{RP}}{P_{amb}} = 1.53$$

$$\frac{P_{RT}}{P_{amb}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

1.2. AR COANNULAR NOZZLE

$\theta = 150^\circ$



	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_{∞} (fps)
————	3432	990	250	1405	600	0
-----	3431					100
————	3430					200
-----	3416	Y	Y	Y	Y	340

$$\frac{P_{4P}}{P_{000}} = 1.53$$

$$\frac{P_{4T}}{P_{000}} = 1.8$$

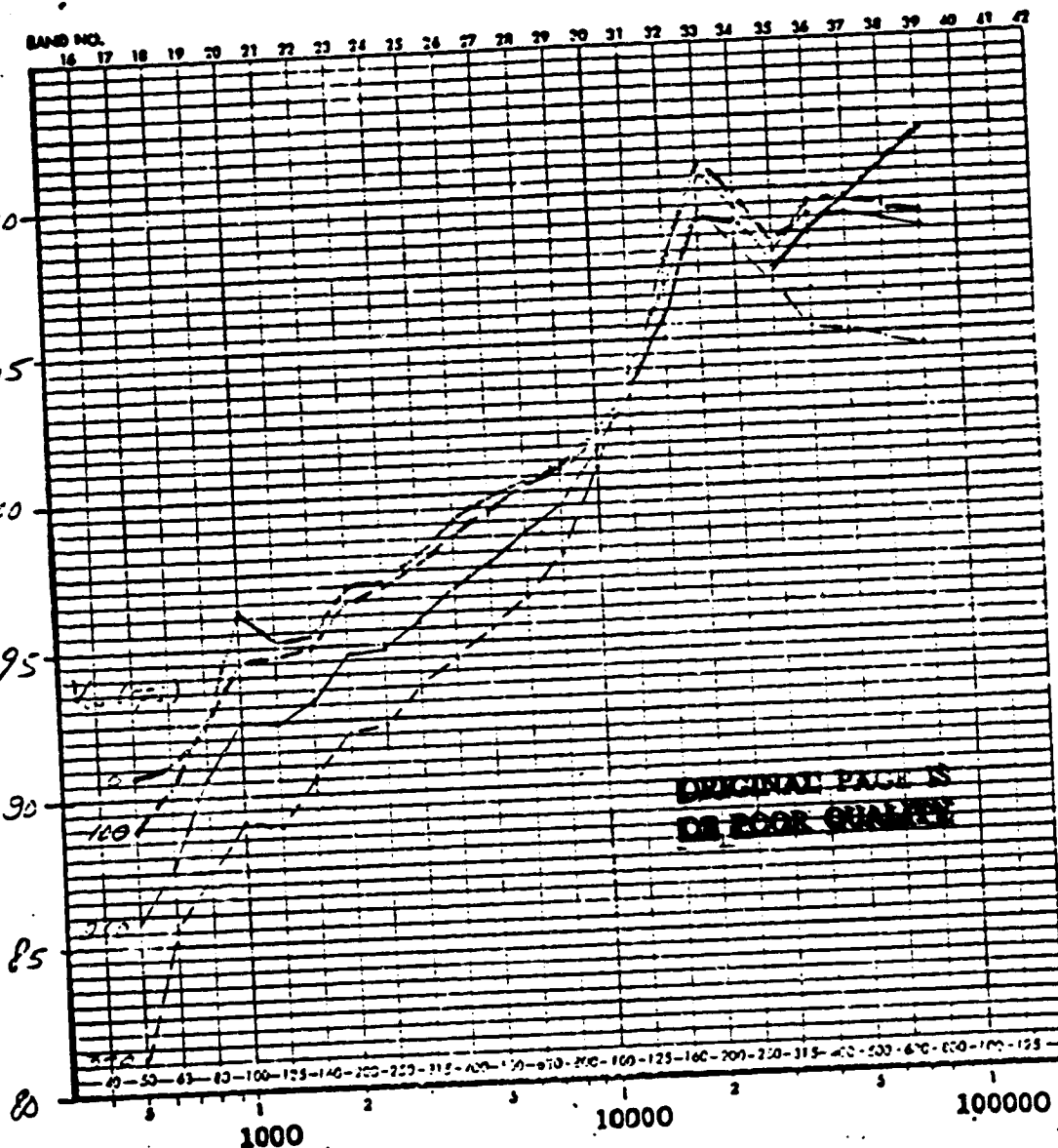
RELATIVE VELOCITY EFFECT ON JET NOISE

1.2 AR COANNULAR NOZZLE

$\theta = 90^\circ$

ADD 49 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~10 FT RADIUS
THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
—————	3426	990	250	1905	600	0
-----	3425	↓	↓	↓	↓	100
-----	3426	↓	↓	↓	↓	200
-----	3425	↓	↓	↓	↓	340
-----	3426	↓	↓	↓	↓	

$$\frac{P_p}{P_{amb}} = 1.53$$

$$\frac{P_f}{P_{amb}} = 3.2$$

RELATIVE VELOCITY EFFECT ON JET NOISE

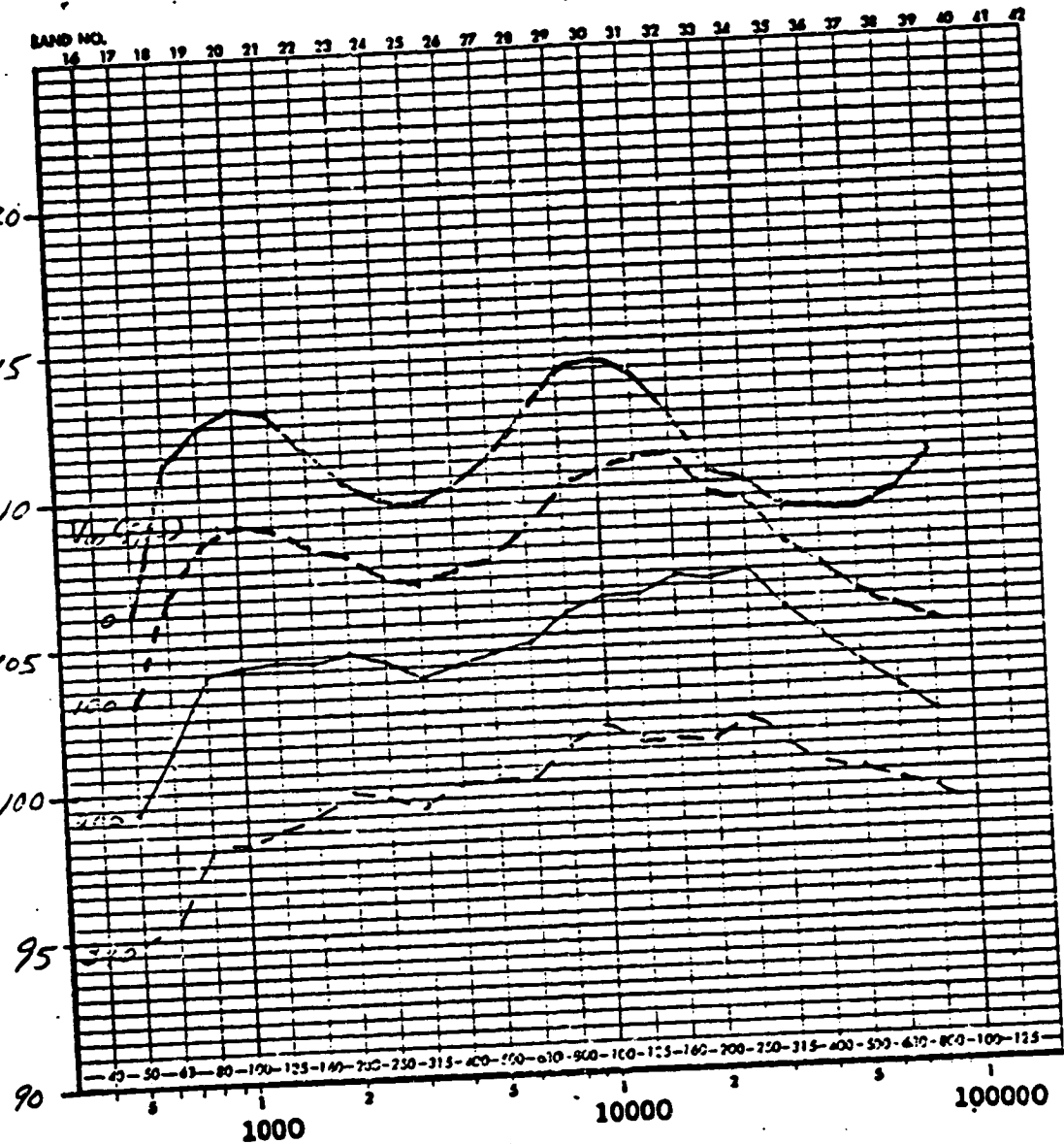
1.2 AR COANNULAR NOZZLE

$\theta = 150^\circ$

ADD 45 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_j (fps)	T_j °F	V_∞ (fps)
————	3426	990	250	1905	600	0
-----	3425	↓	↓	↓	↓	100
————	3424	↓	↓	↓	↓	200
-----	3414	↓	↓	↓	↓	300

$$\frac{P_{jet}}{P_{amb}} = 1.53$$

$$\frac{P_{jet}}{P_{amb}} = 3.2$$

RELATIVE VELOCITY EFFECT ON JET NOISE

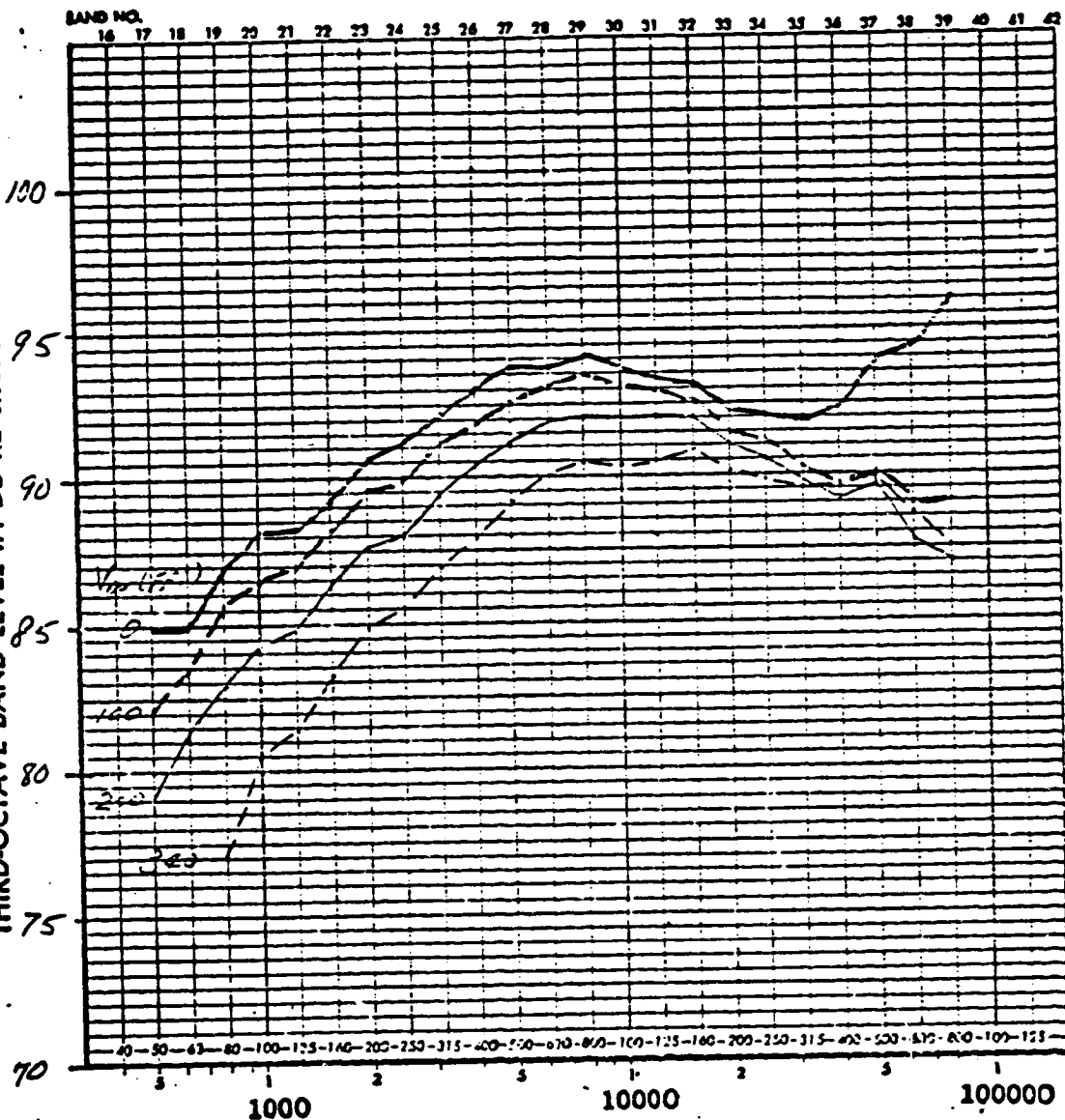
1.2 AR COANNULAR NOZZLE

$\theta = 90^\circ$

ADD 45 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_∞ (fps)
————	3406	990	250	1535	800	0
-----	3409					100
————	3410					200
-----	3422	↓	↓	↓	↓	340

$$\frac{P_{t1}}{P_{amb}} = 1.53$$

$$\frac{P_{t2}}{P_{amb}} = 1.8$$

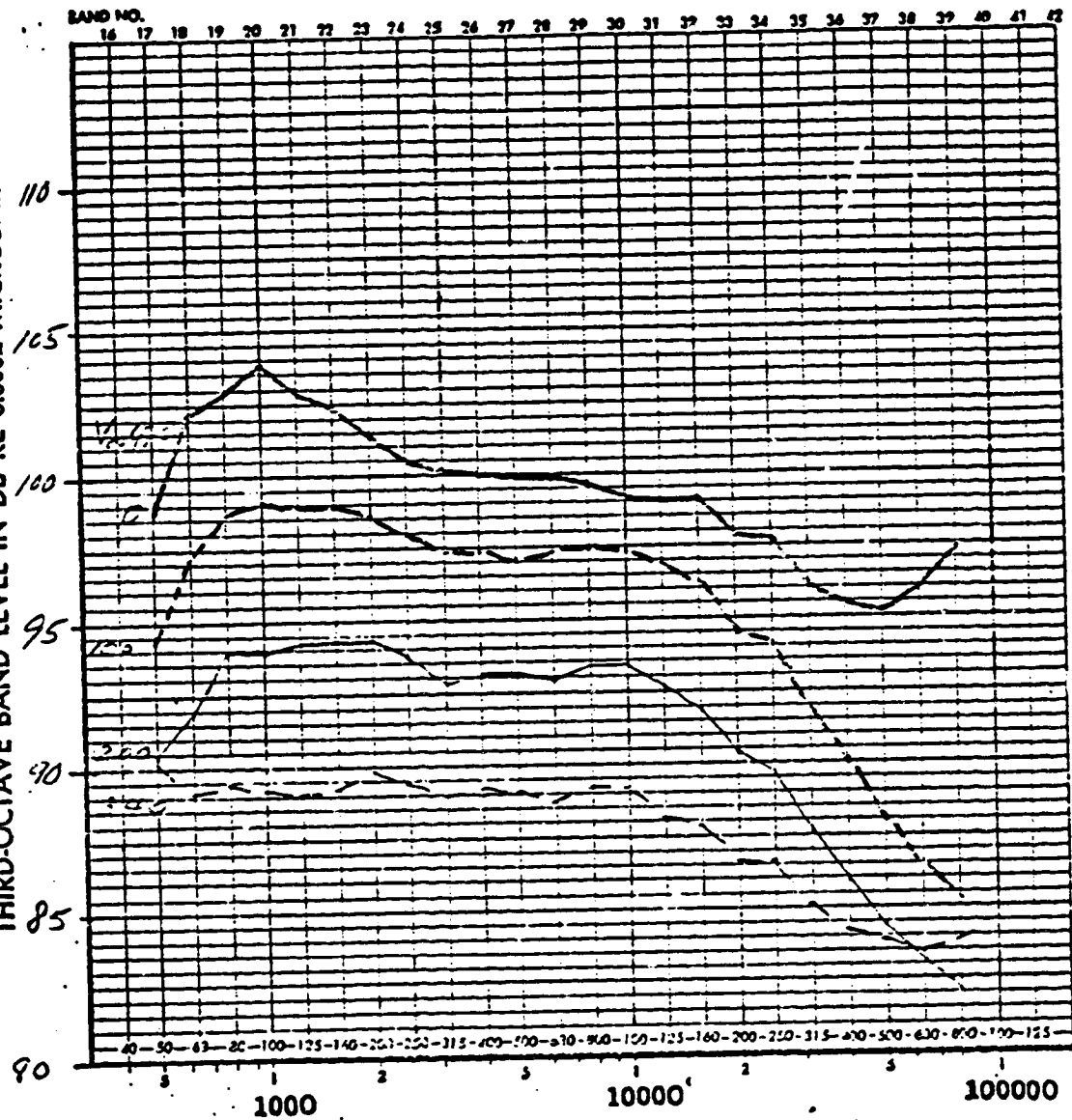
RELATIVE VELOCITY EFFECT ON JET NOISE

1.2 AR COANNULAR NOZZLE

$\theta = 150^\circ$

ADD 42 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~10 FT RADIUS
THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



FREQUENCY IN HERTZ

	RUN NO.	V_D (fps)	T_D °F	V_f (fps)	T_f °F	V_{∞} (fps)
————	3408	990	250	1535	800	0
— — —	3409	↓	↓	↓	↓	100
————	3410	↓	↓	↓	↓	200
— — —	3422	↓	↓	↓	↓	540

$$\frac{P_{t,f}}{P_{t,b}} = 1.53$$

$$\frac{P_{t,f}}{P_{t,b}} = 1.8$$

RELATIVE VELOCITY EFFECT ON JET NOISE

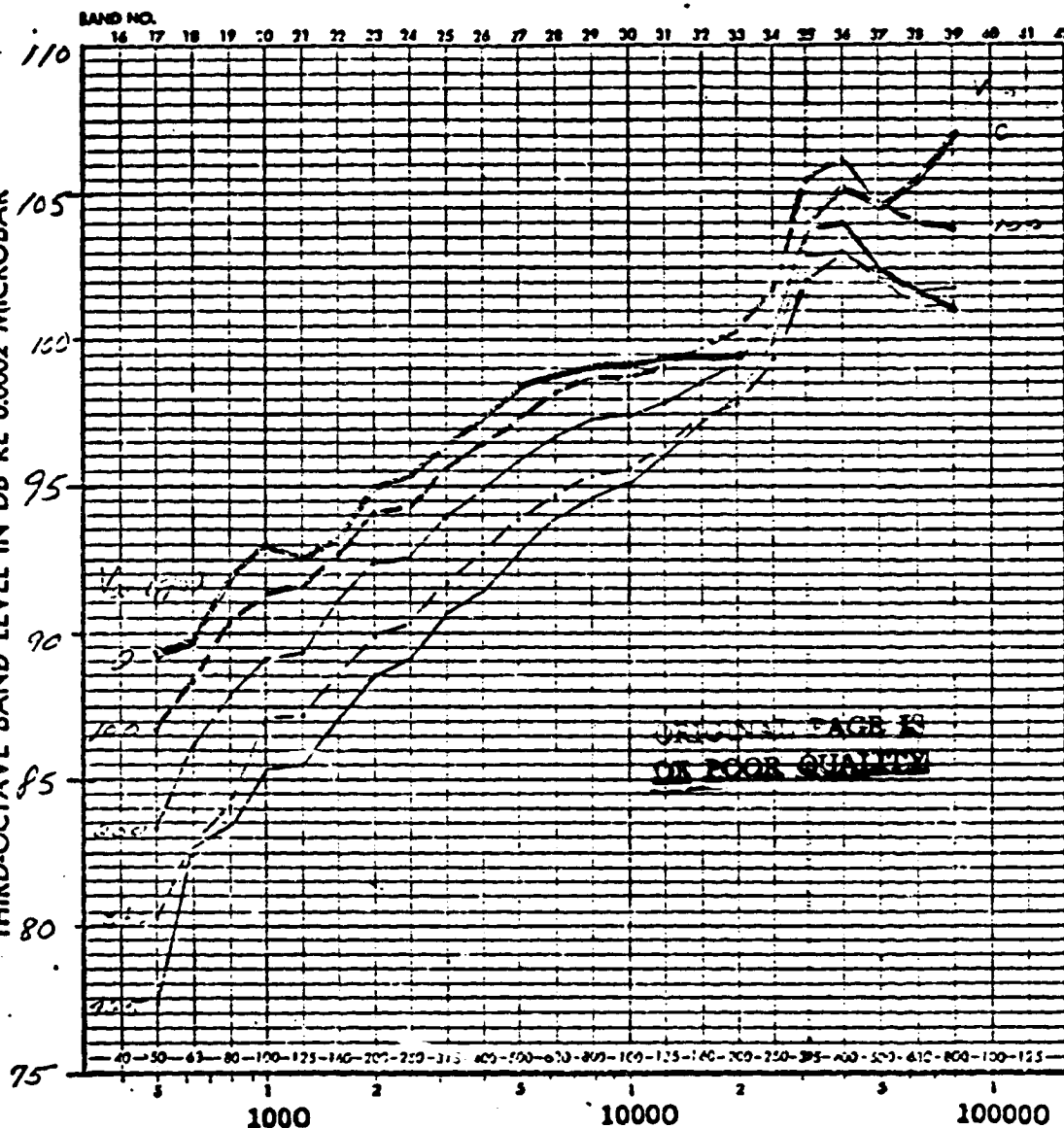
1.2 AR CONNULAR NOZZLE

$\theta = 90^\circ$

ADD 4.9 DB TO OBTAIN OCTAVE BAND LEVEL

SOUND PRESSURE LEVEL ~ 10 FT RADIUS

THIRD-OCTAVE BAND LEVEL IN DB RE 0.0002 MICROBAR



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FREQUENCY IN HERTZ

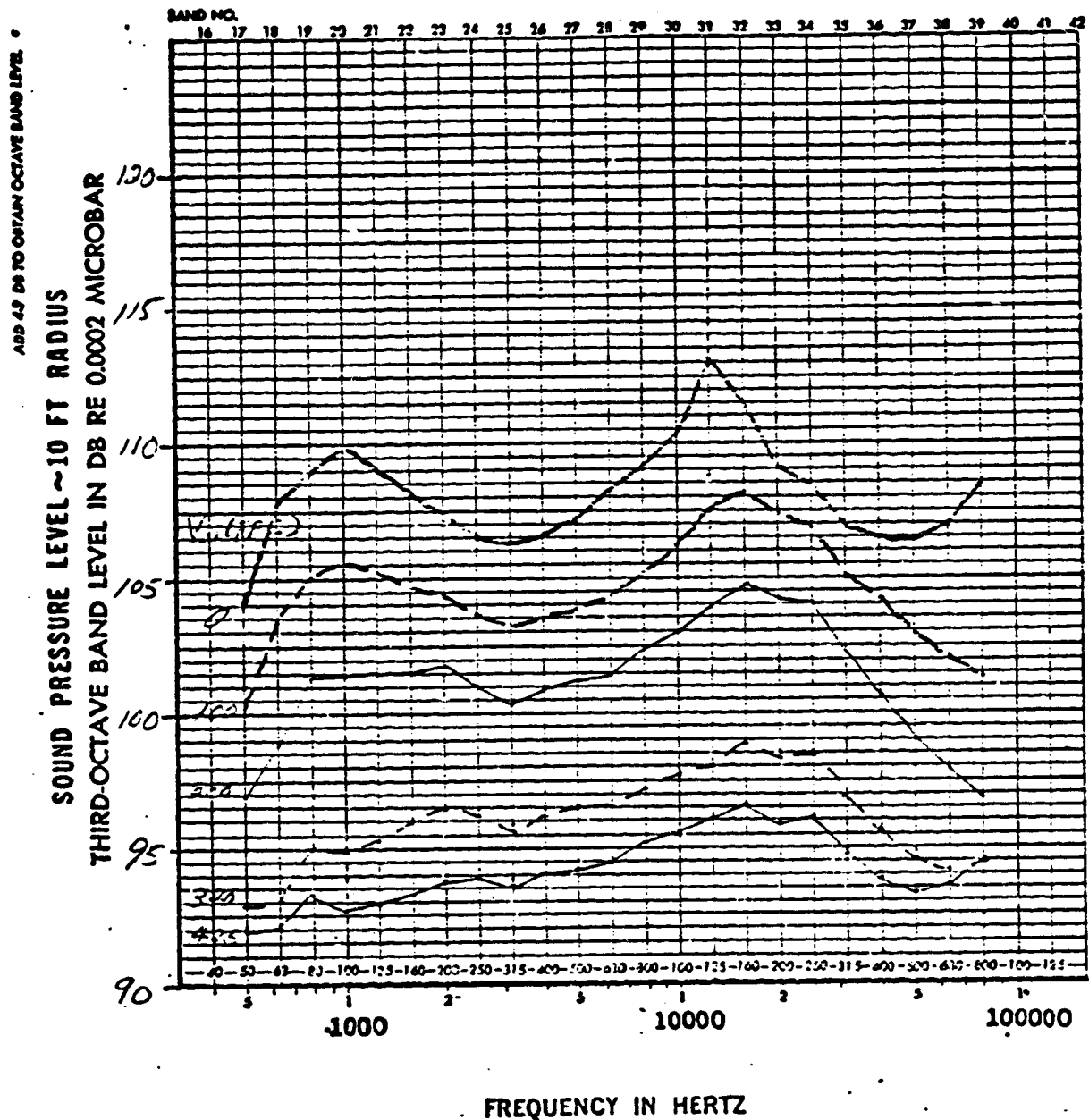
	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_{oz} (fps)
————	3407	990	250	1825	800	0
-----	3406	↓	↓	↓	↓	100
————	3404	↓	↓	↓	↓	200
-----	3427	↓	↓	↓	↓	340
————	3421	↓	↓	↓	↓	425

$$\frac{P_{ep}}{P_{no}} = 1.53$$

$$\frac{P_{et}}{P_{no}} = 2.5$$

RELATIVE VELOCITY EFFECT ON JET NOISE

1.2 AR COANNULAR NOZZLE $\theta=150^\circ$

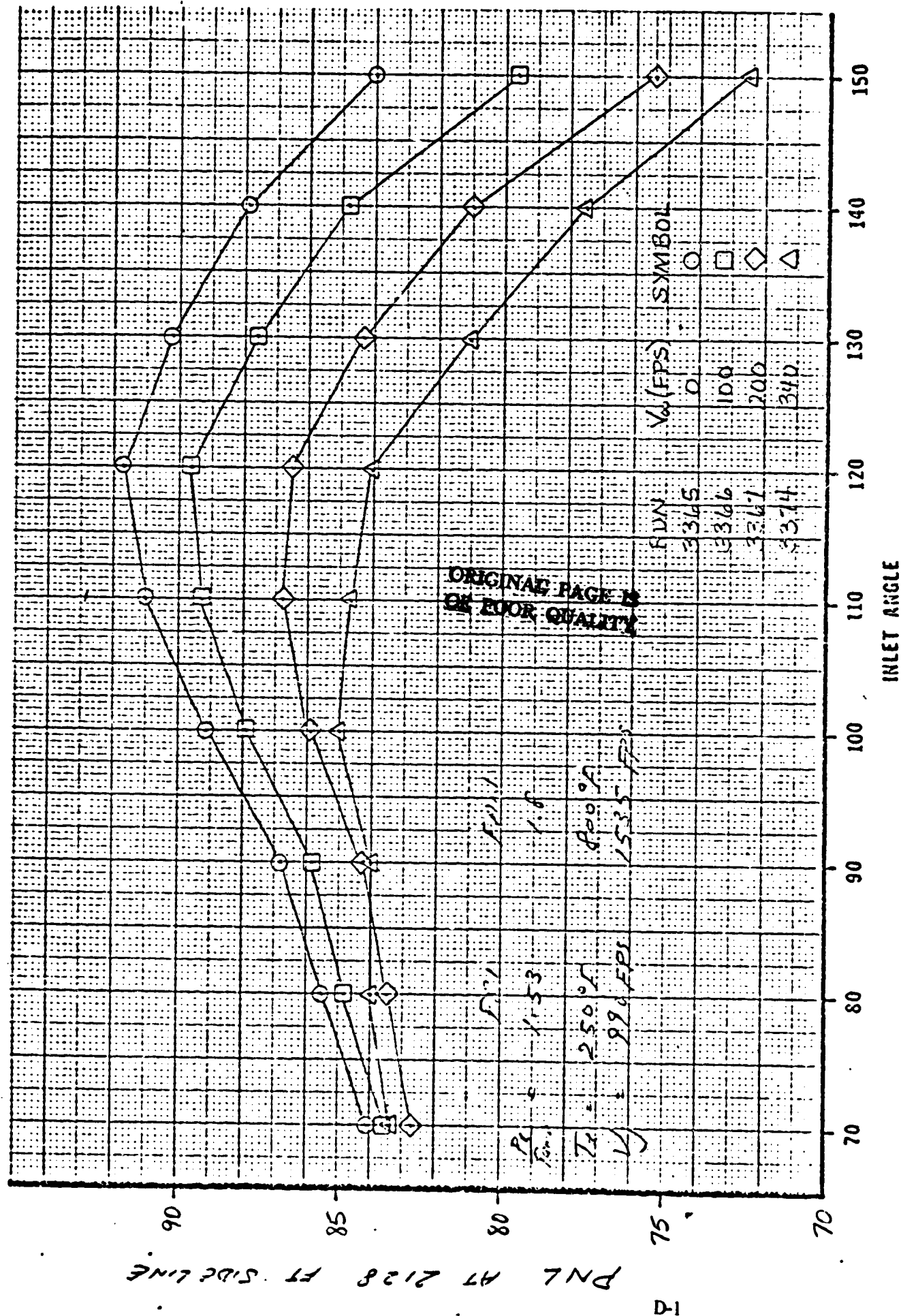


	RUN NO.	V_p (fps)	T_p °F	V_f (fps)	T_f °F	V_{∞} (fps)
—————	23-7	990	250	1875	800	0
-----	24-6					100
—————	25-2					200
-----	34-20					300
—————	26-21	Y	Y	Y	Y	425

$$\frac{P_{11}}{P_{amb}} = 1.53$$

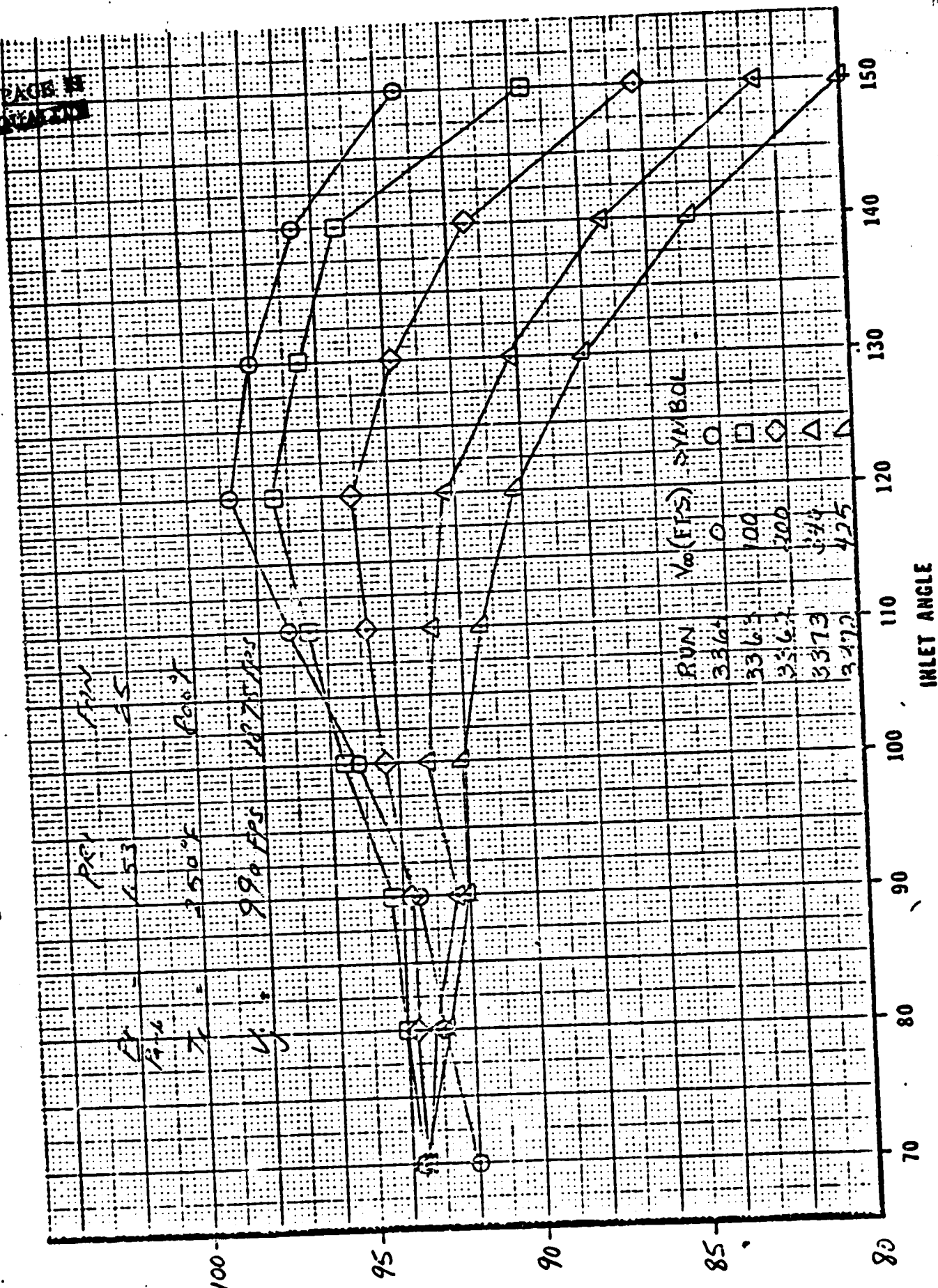
$$\frac{P_{11}}{P_{amb}} = 2.5$$

0.75 AR CONN₄ LAR NOZZLE



DIRECTIVITY 0.75 AR CONNULAR NOZZLE

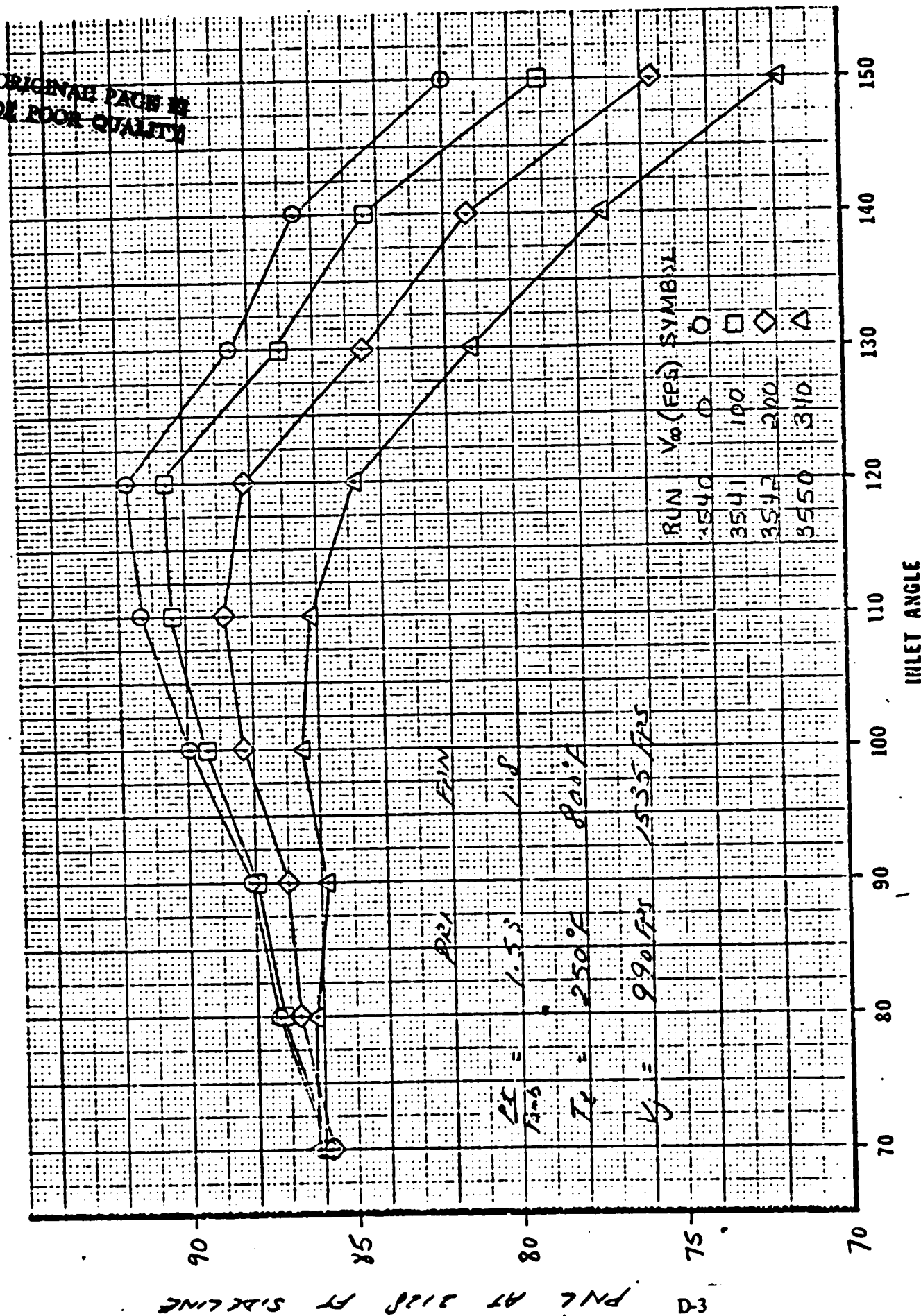
P.N.L. AT 2128 FT SIDELINE



DIRECTIVITY

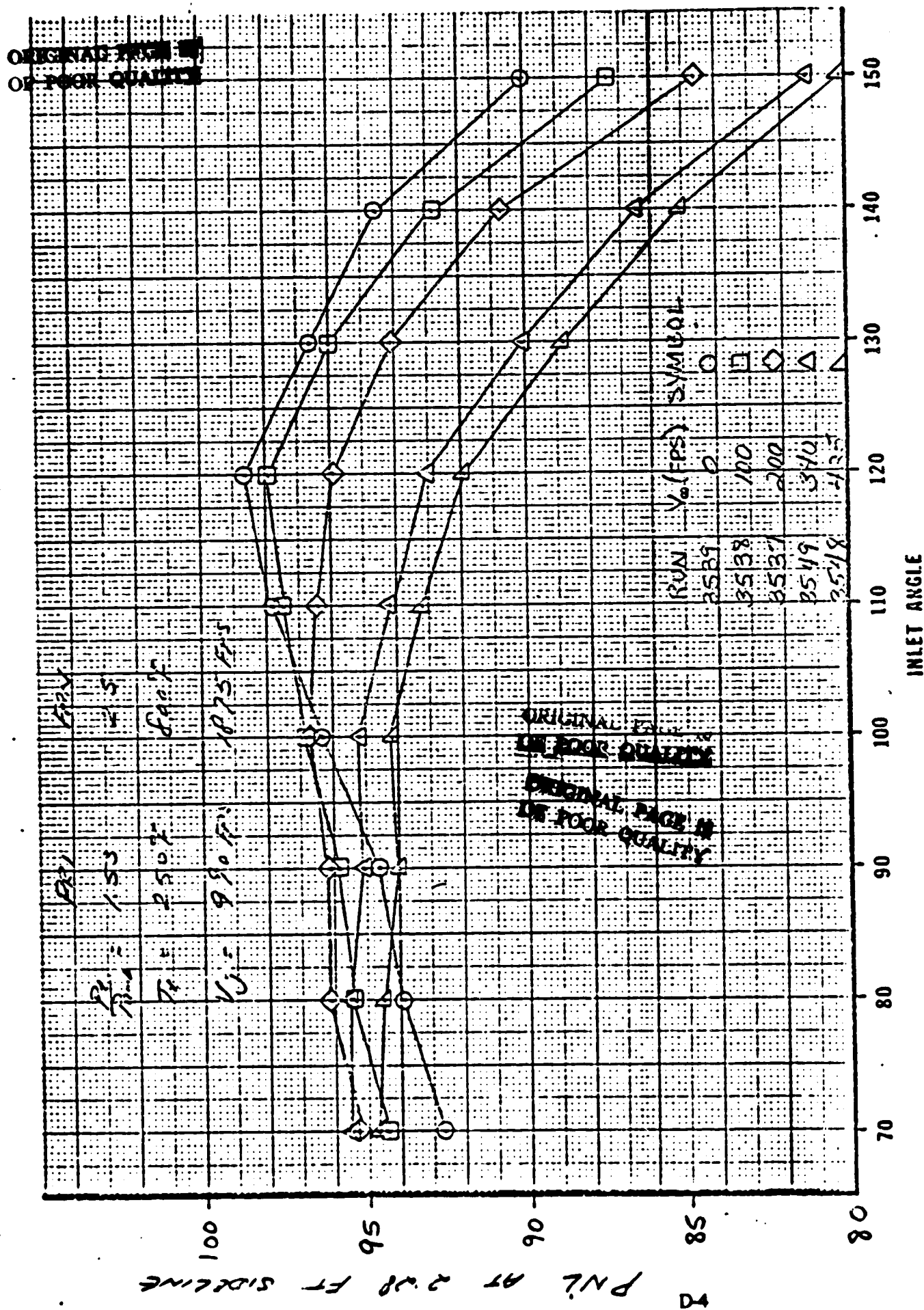
0.75 AR CANNULAR NOZZLE WITH EJECTOR

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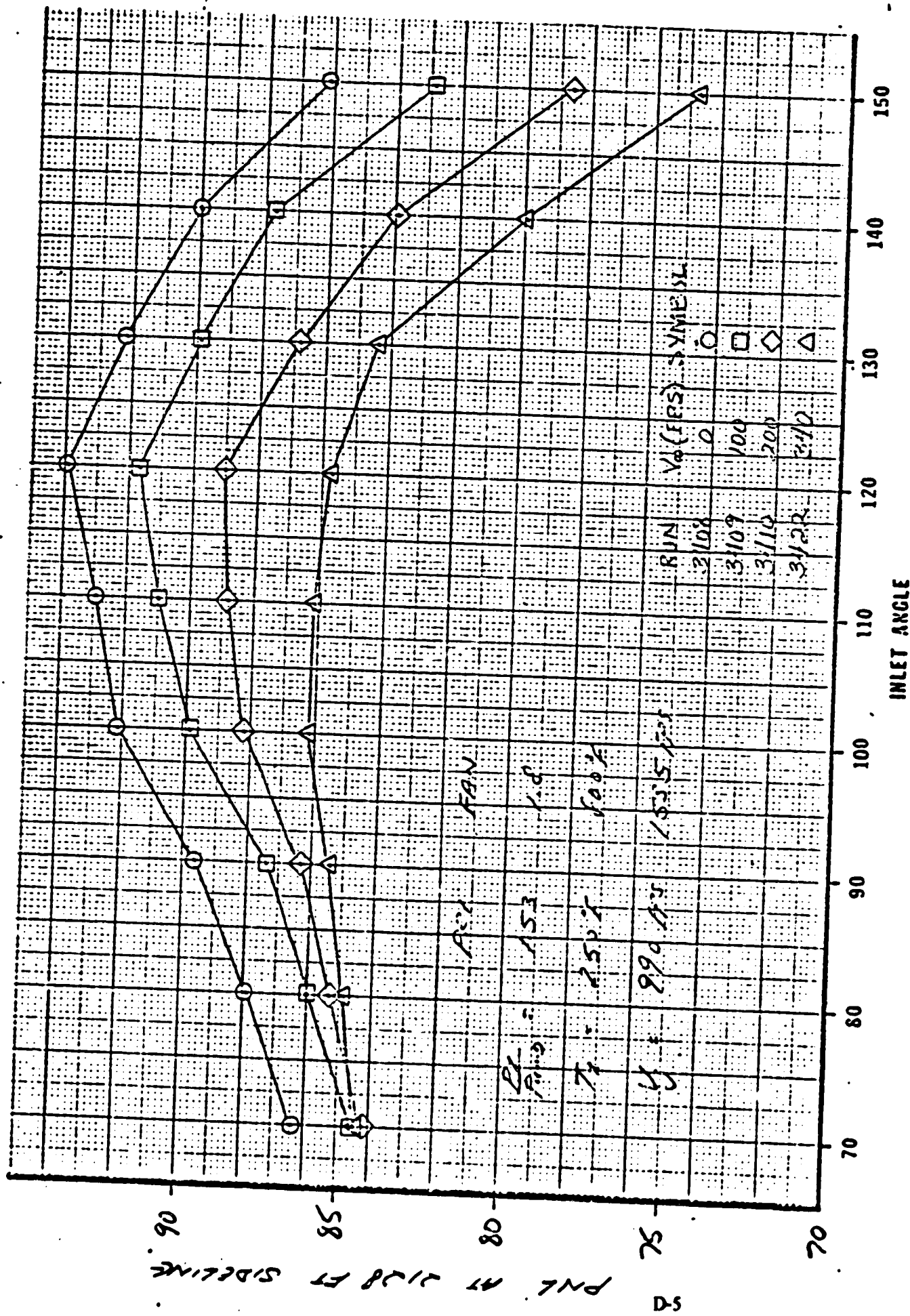
DIRECTIVITY

0.75 AR CONNULAR NOZZLE WITH EJECTOR



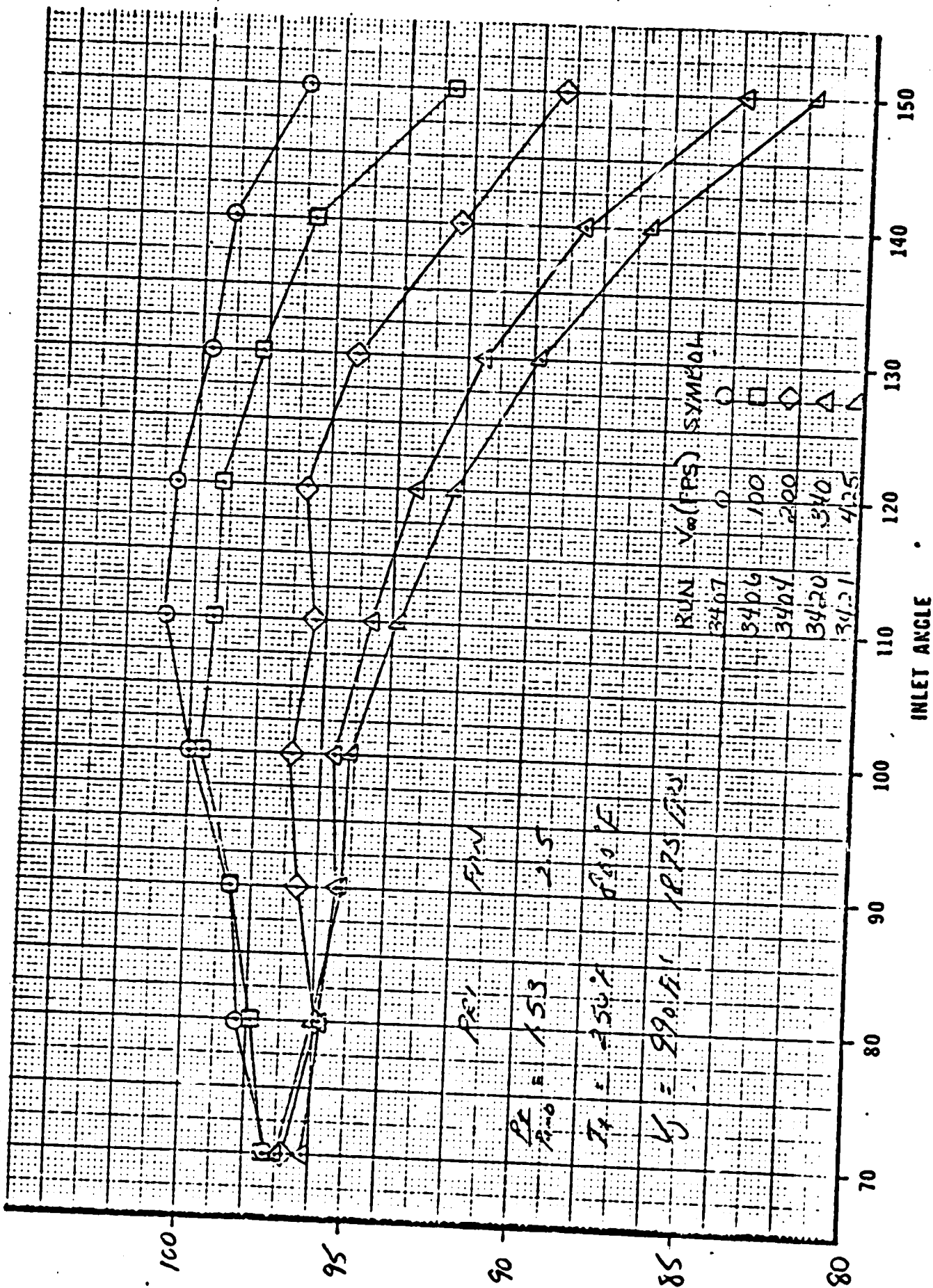
DIRECTIVITY CONJUGAL NOZZLE

1.2 AR



DIRECTIVITY

1.2 AR CONNULAR NOZZLE

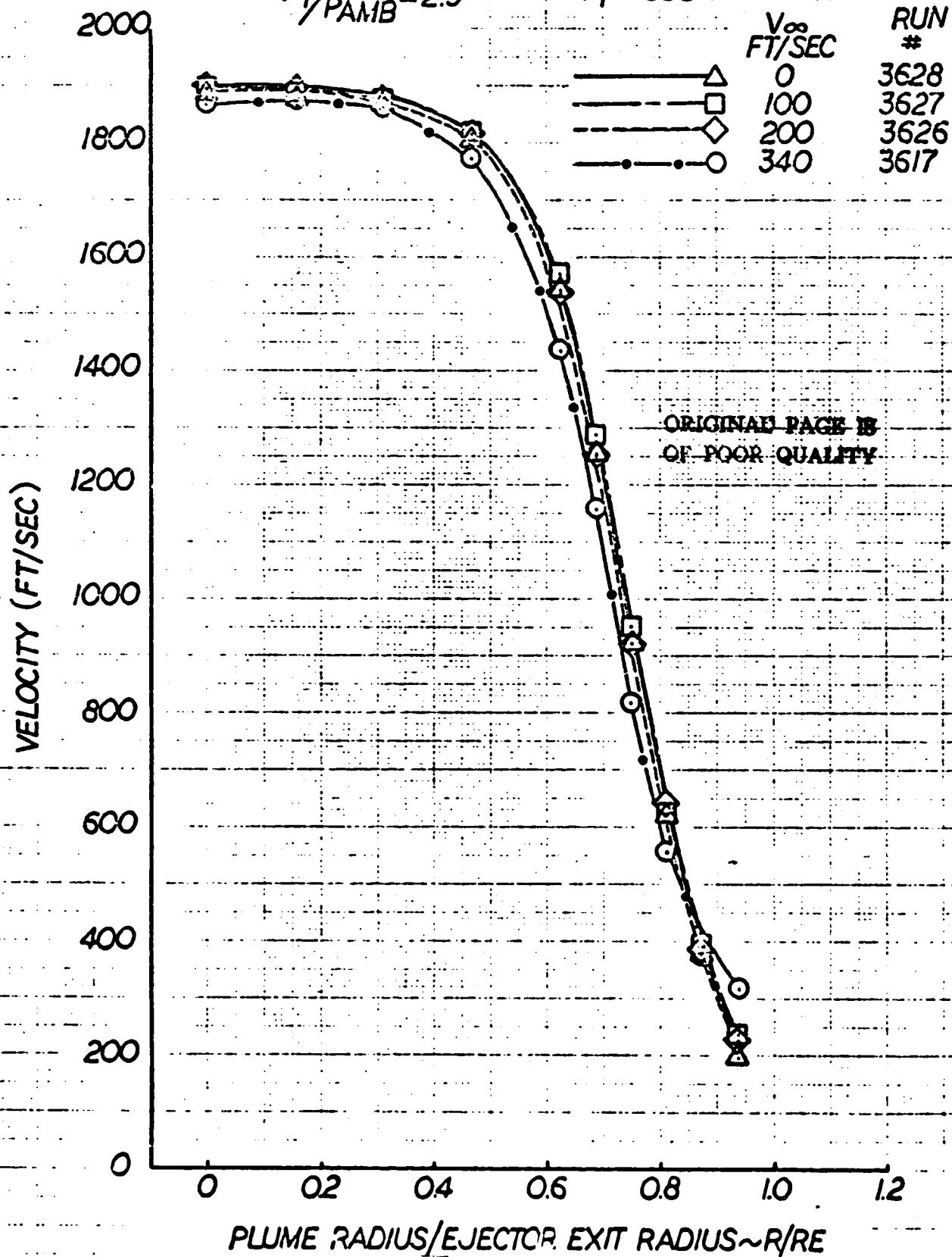


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NOZZLE EXIT VELOCITY PROFILES (1) CONVERGENT NOZZLE

$$P_T/P_{AMB} = 2.5$$

$$T_T = 800^\circ F$$

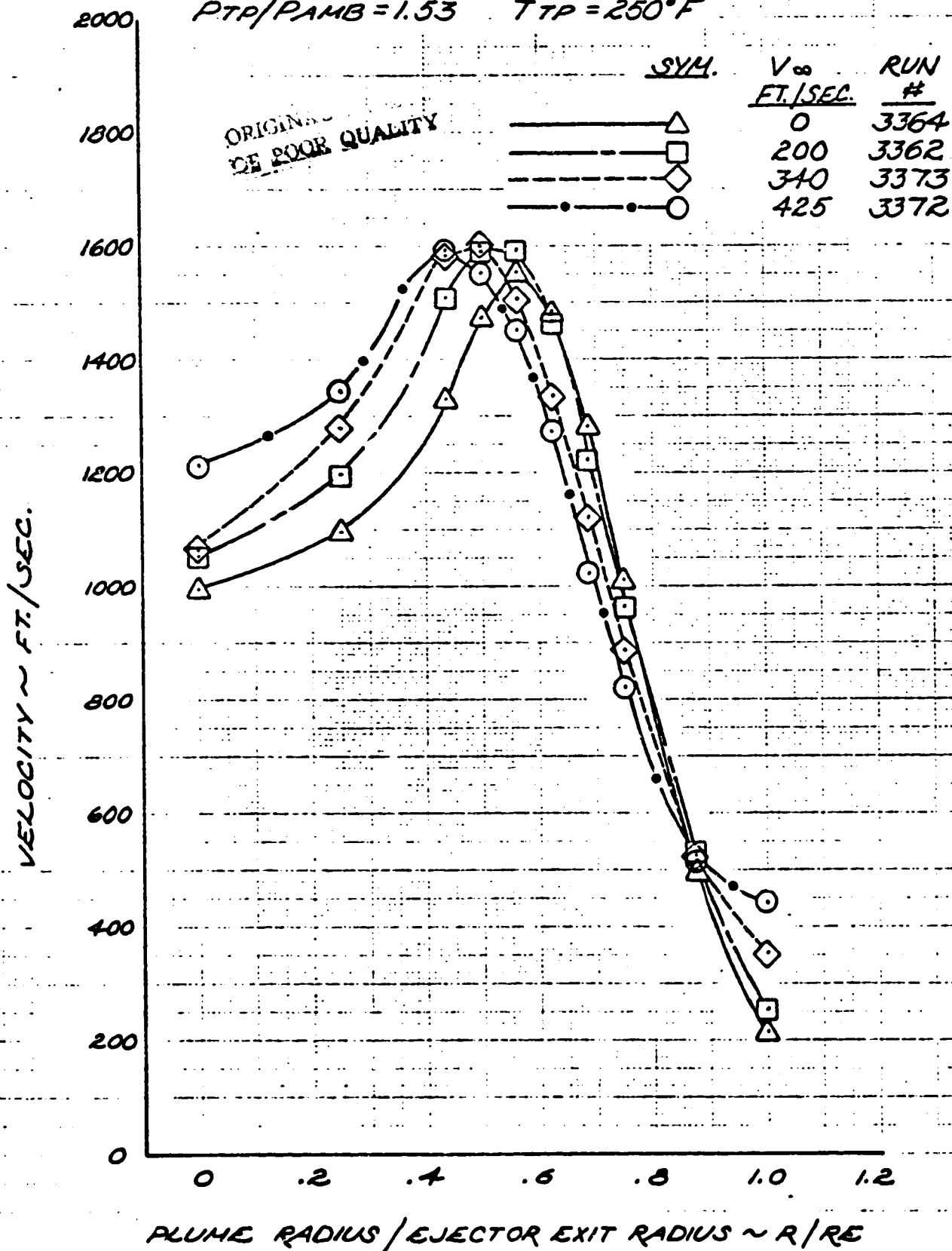


NOZZLE EXIT VELOCITY PROFILES (2) 0.75 AR COANNULAR NOZZLE

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$P_{TF}/P_{AMB} = 2.5$
 $P_{TP}/P_{AMB} = 1.53$

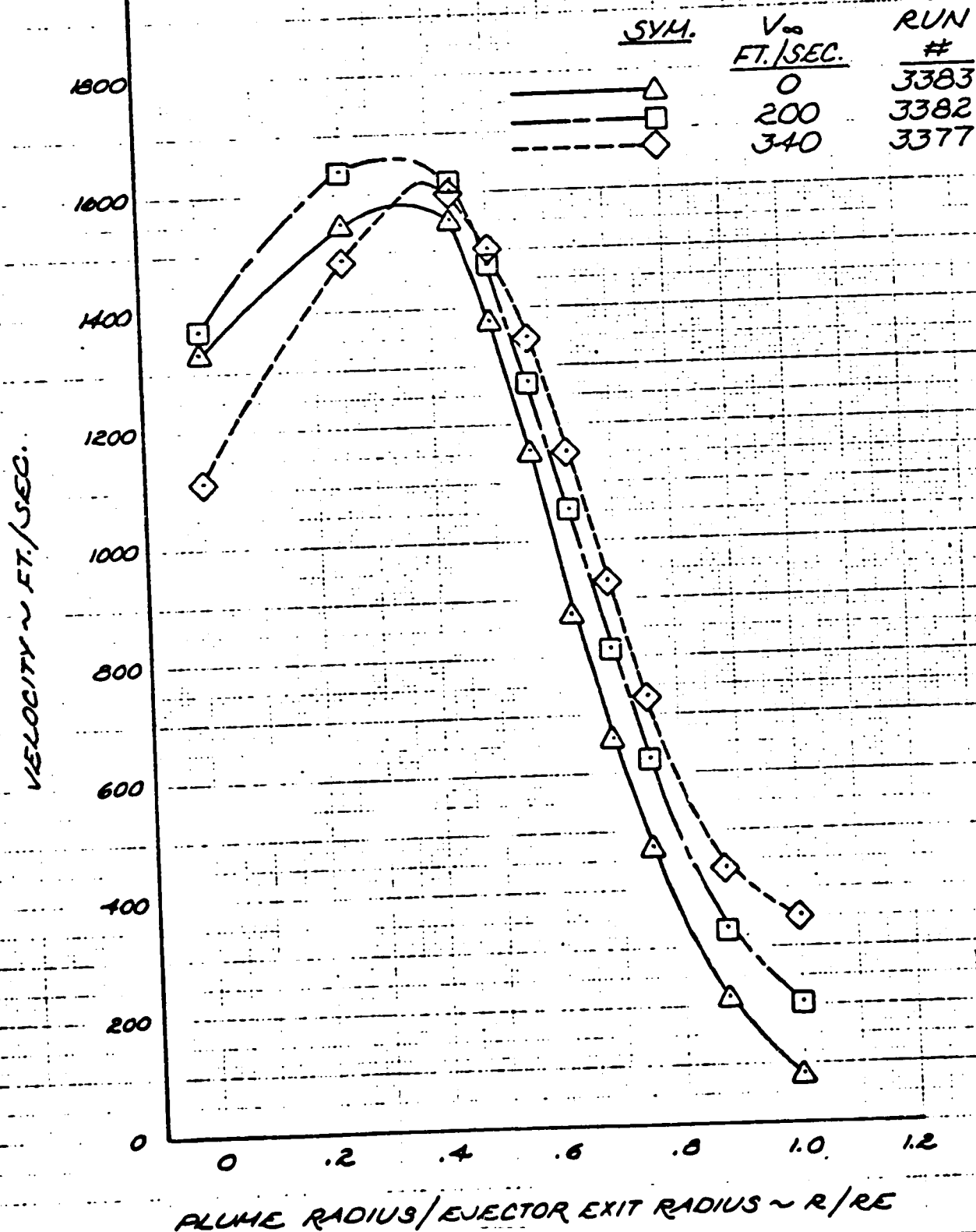
$T_{TF} = 800^{\circ}F$
 $T_{TP} = 250^{\circ}F$



NOZZLE EXIT VELOCITY PROFILES (2) 0.75 AR COANNULAR NOZZLE - FAN FLOW ONLY

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$$P_{TF}/P_{AMB} = 2.5 \quad T_{TF} = 800^{\circ}F$$



NOZZLE EXIT VELOCITY PROFILE (3) 0.75 AR COANNULAR NOZZLE WITH EJECTOR

$P_{TF}/P_{AMB} = 1.3$

$T_{TF} = 800^{\circ}\text{F}$

$P_{TP}/P_{AMB} = 1.53$

$T_{TP} = 250^{\circ}\text{F}$

V_{∞}
FT/SEC

RUN
#

0

3545

200

3543

340

3551

425

3556

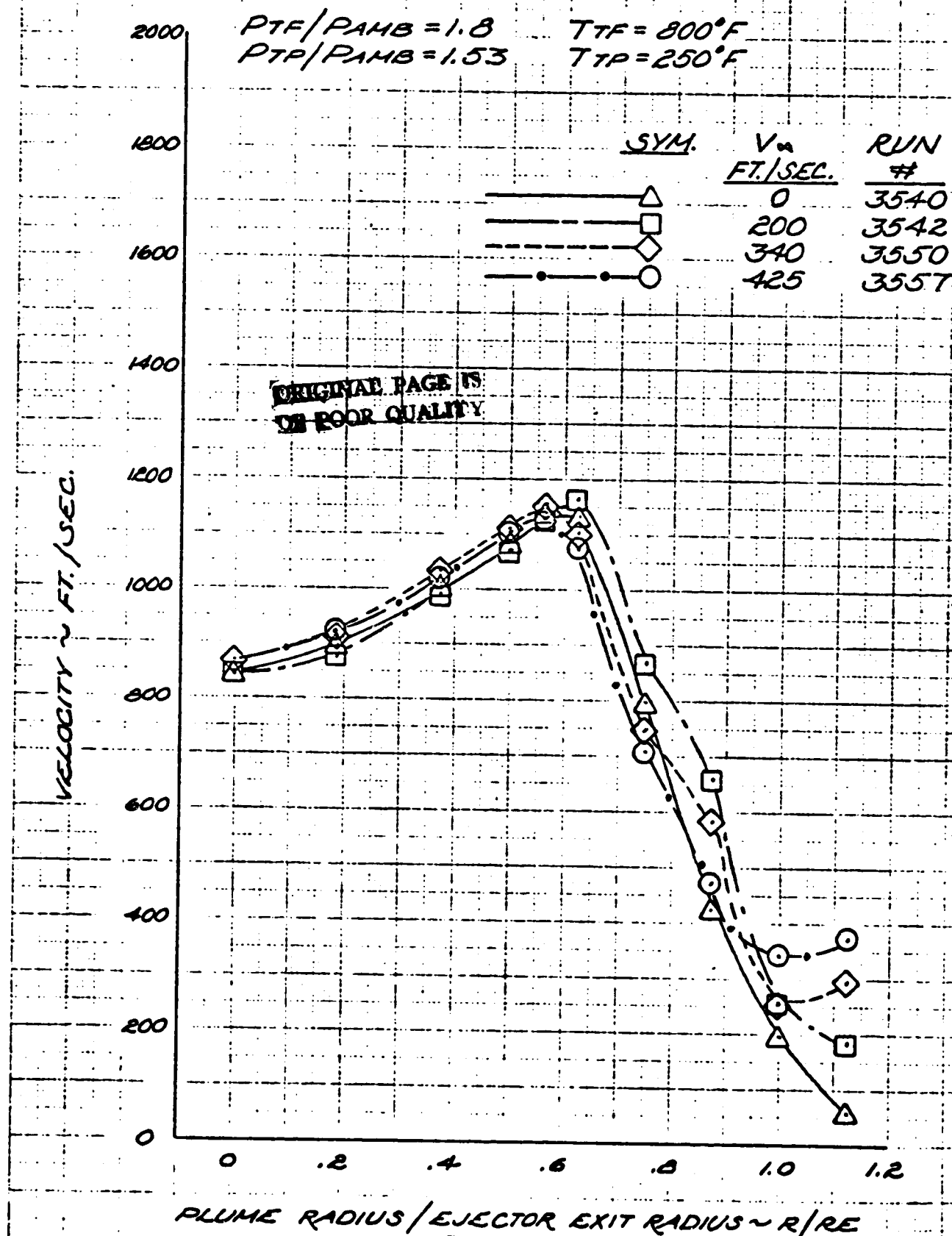
VELOCITY (FT/SEC)

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PLUME RADIUS/EJECTOR EXIT RADIUS $\sim R/R_E$

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(3)

NOZZLE EXIT VELOCITY PROFILES 0.75 AR COANNULAR NOZZLE WITH EJECTOR



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NOZZLE EXIT VELOCITY PROFILES (3) 0.75 AR COANNULAR NOZZLE WITH EJECTOR

$P_{TF}/P_{AMB} = 25$

$T_{TF} = 800^{\circ}F$

$P_{TP}/P_{AMB} = 1.53$

$T_{TP} = 250^{\circ}F$

V_{∞}
FT/SEC

RUN
#

0

3539

200

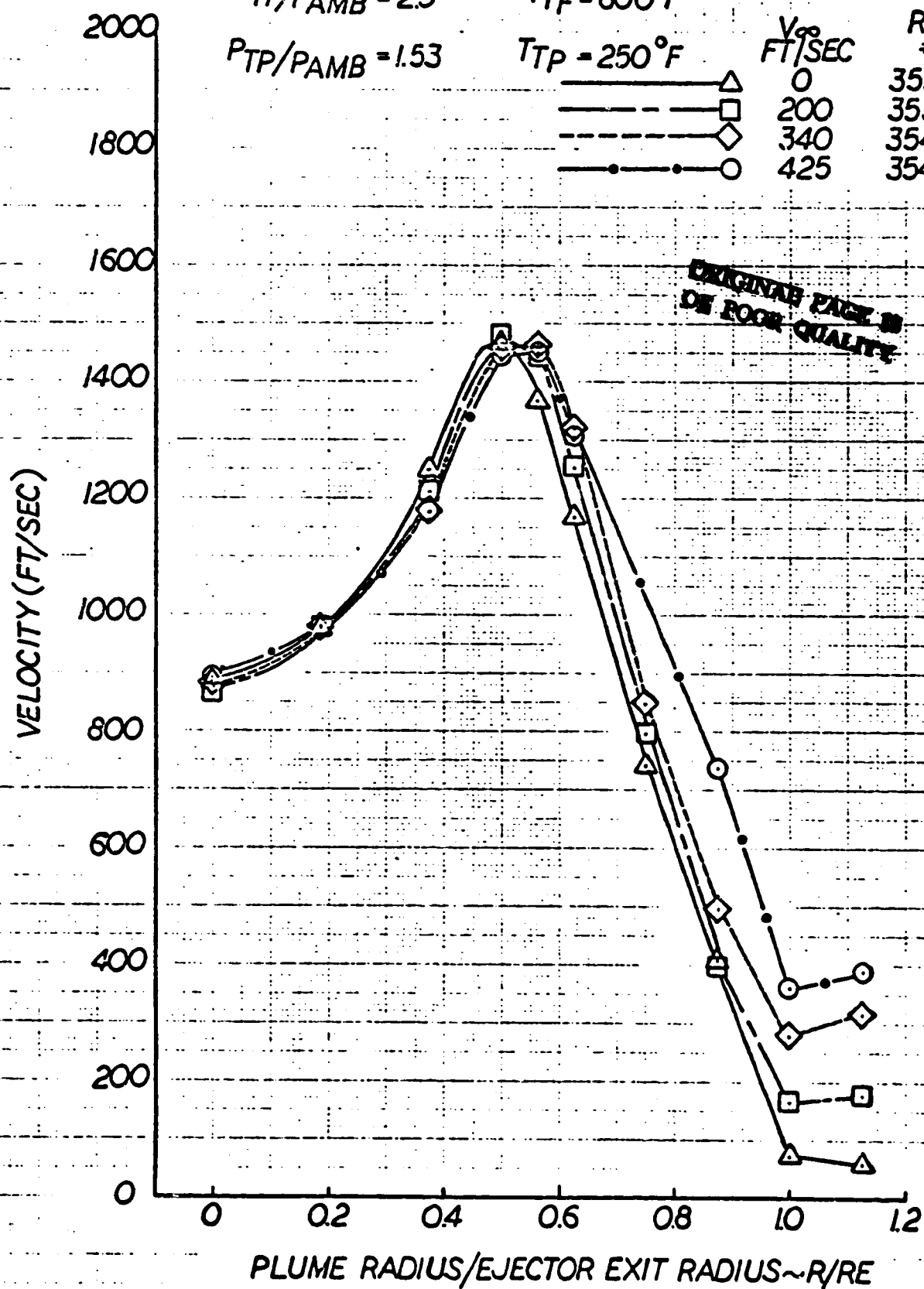
3537

340

3549

425

3548



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NOZZLE EXIT VELOCITY PROFILES
(3) 0.75 AR COANNULAR NOZZLE WITH EJECTOR

$P_{TF}/P_{AMB} = 3.2$

$T_{TF} = 800^{\circ}\text{F}$

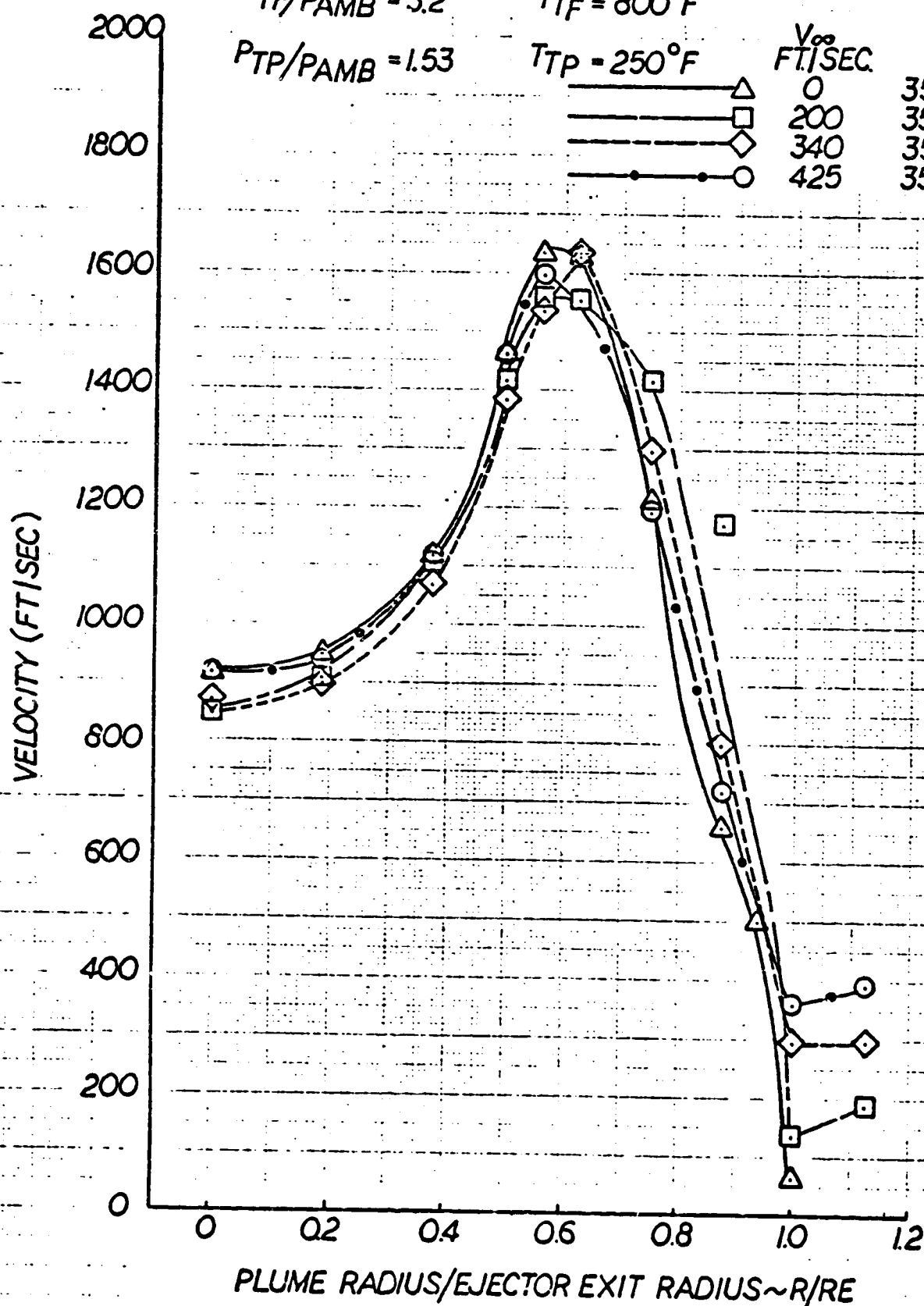
$P_{TP}/P_{AMB} = 1.53$

$T_{TP} = 250^{\circ}\text{F}$

V_{∞}
FT./SEC.

RUN

0	3534
200	3536
340	3546
425	3547

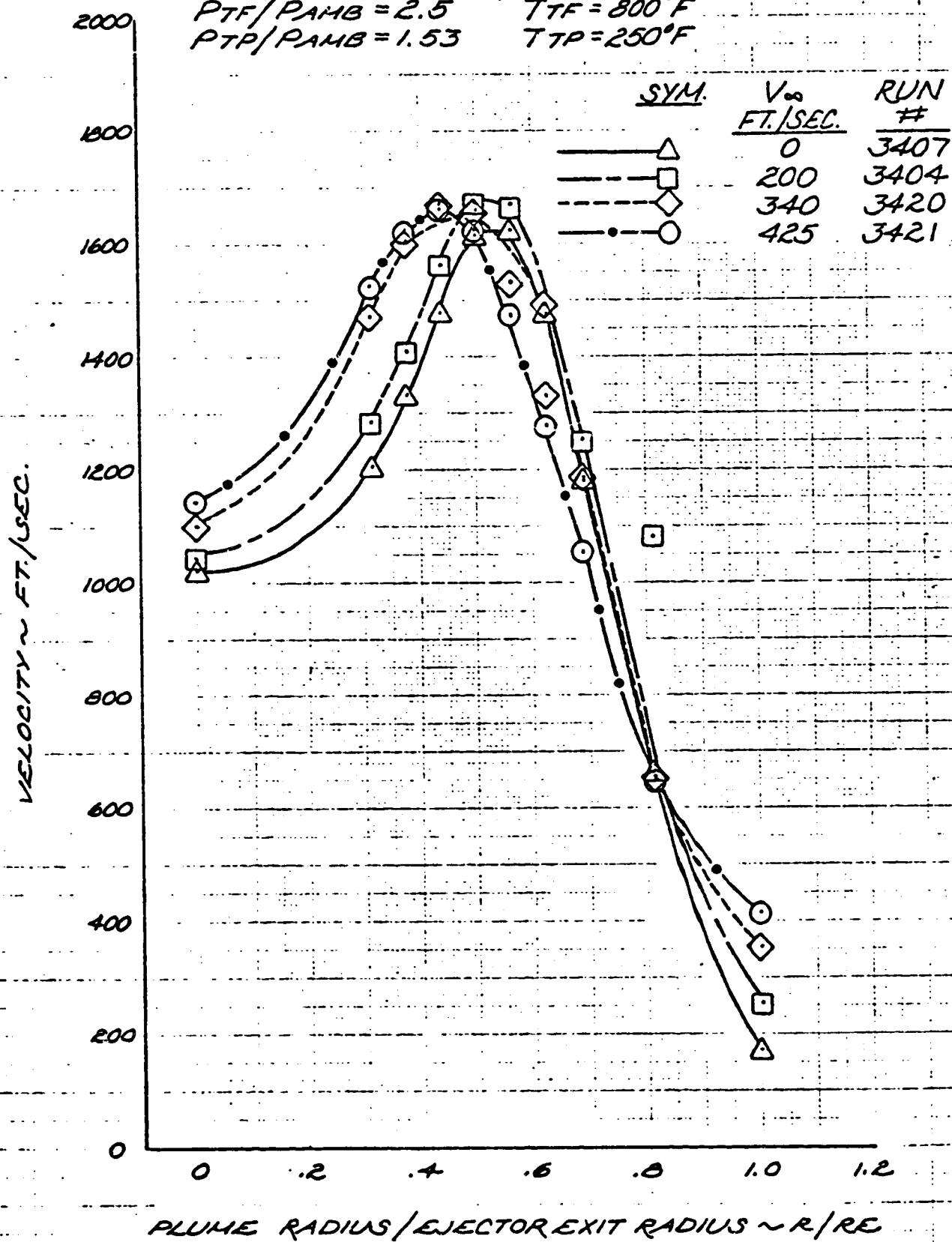


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NOZZLE EXIT VELOCITY PROFILES (4) 1.2 AR COANNULAR NOZZLE

$P_{TF}/P_{AMB} = 2.5$
 $P_{TP}/P_{AMB} = 1.53$

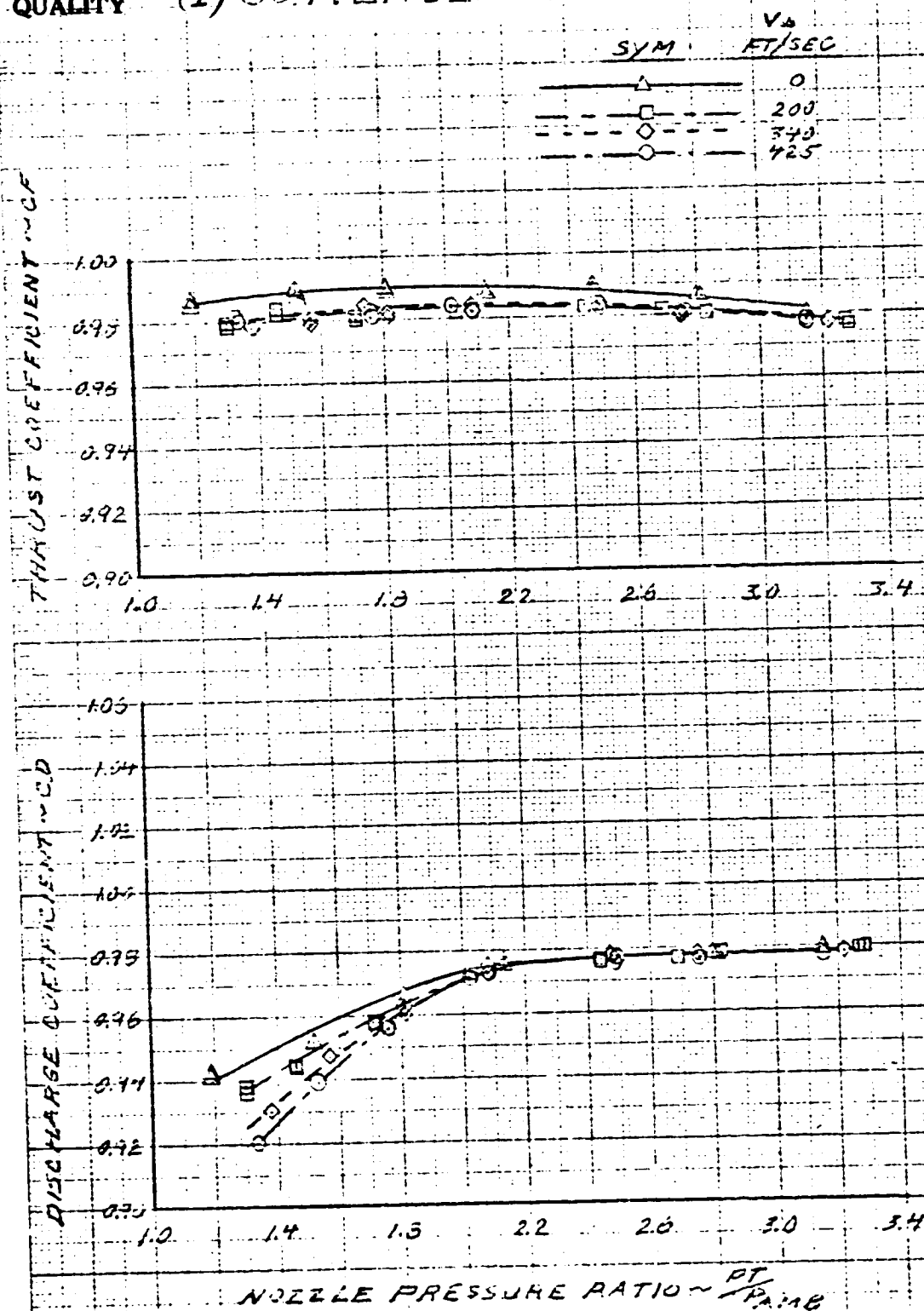
$T_{TF} = 800^{\circ}F$
 $T_{TP} = 250^{\circ}F$



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NOZZLE PERFORMANCE

(1) CONVERGENT NOZZLE



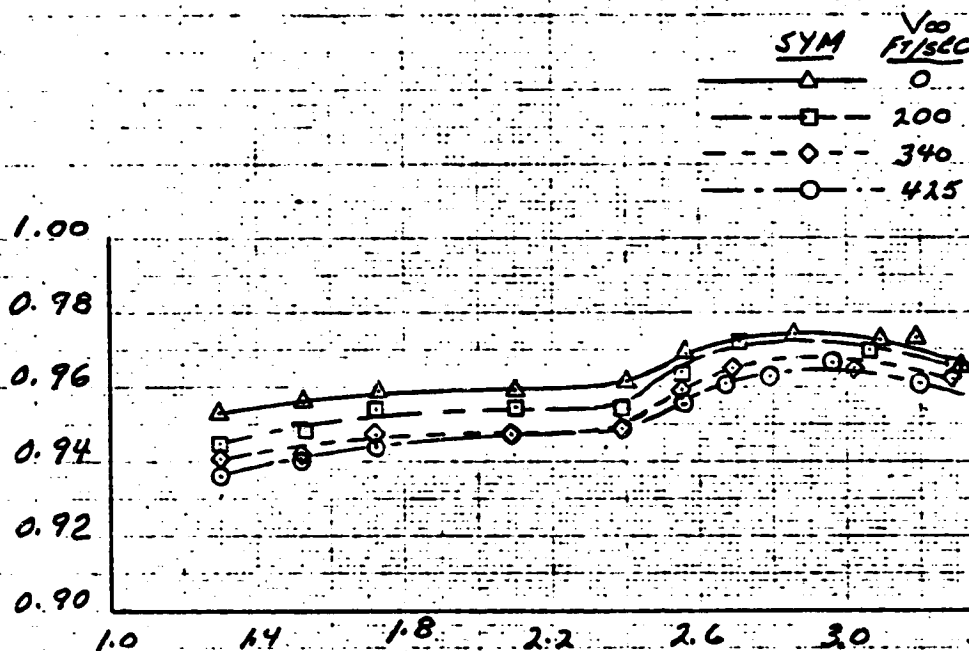
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NOZZLE PERFORMANCE

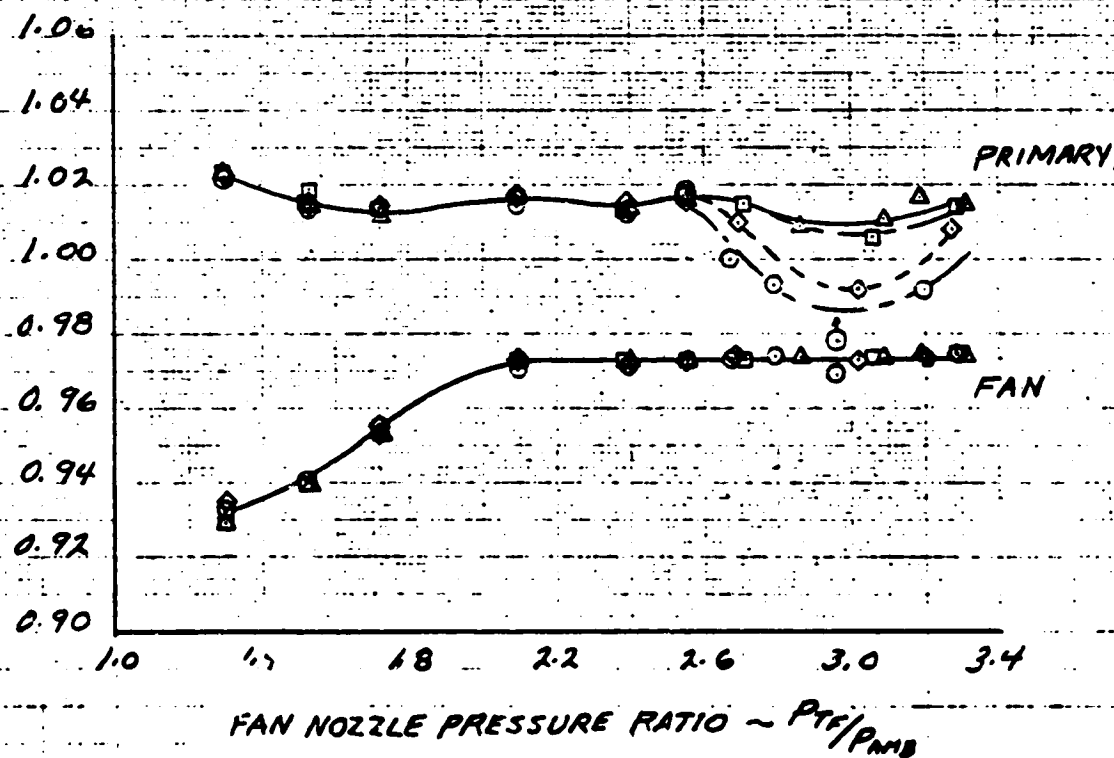
(2) 0.75 AR COANNULAR NOZZLE

PRIMARY NOZZLE PRESSURE RATIO $P_{TP}/P_{AMB} = 1.53$

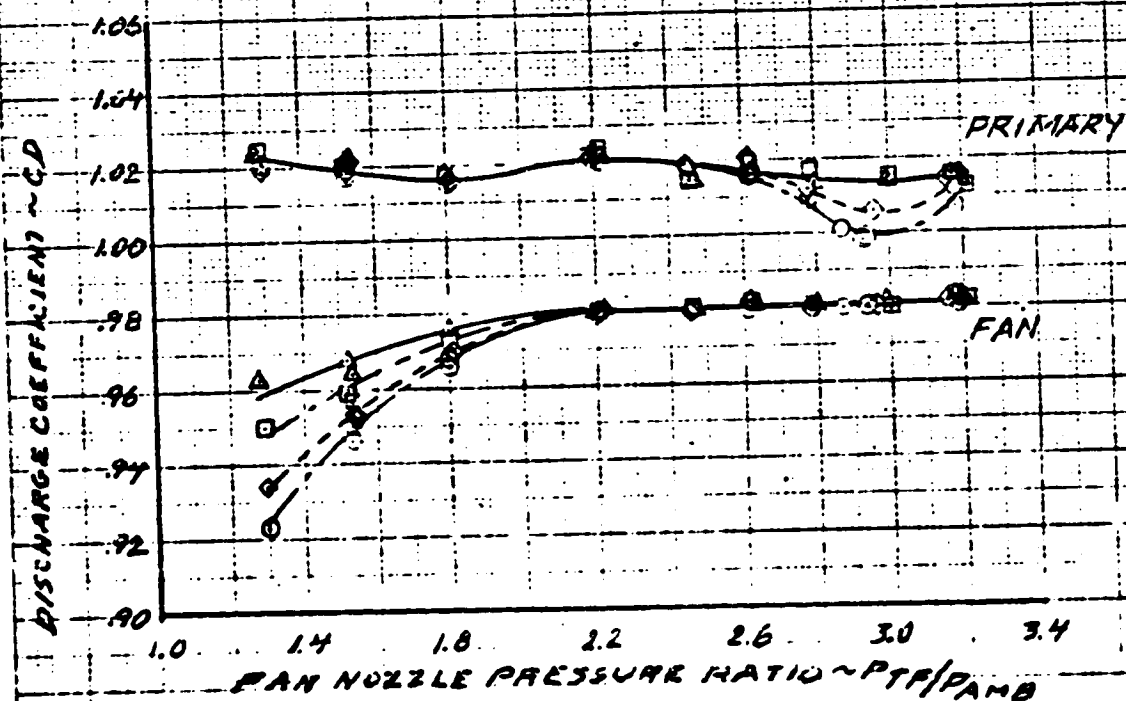
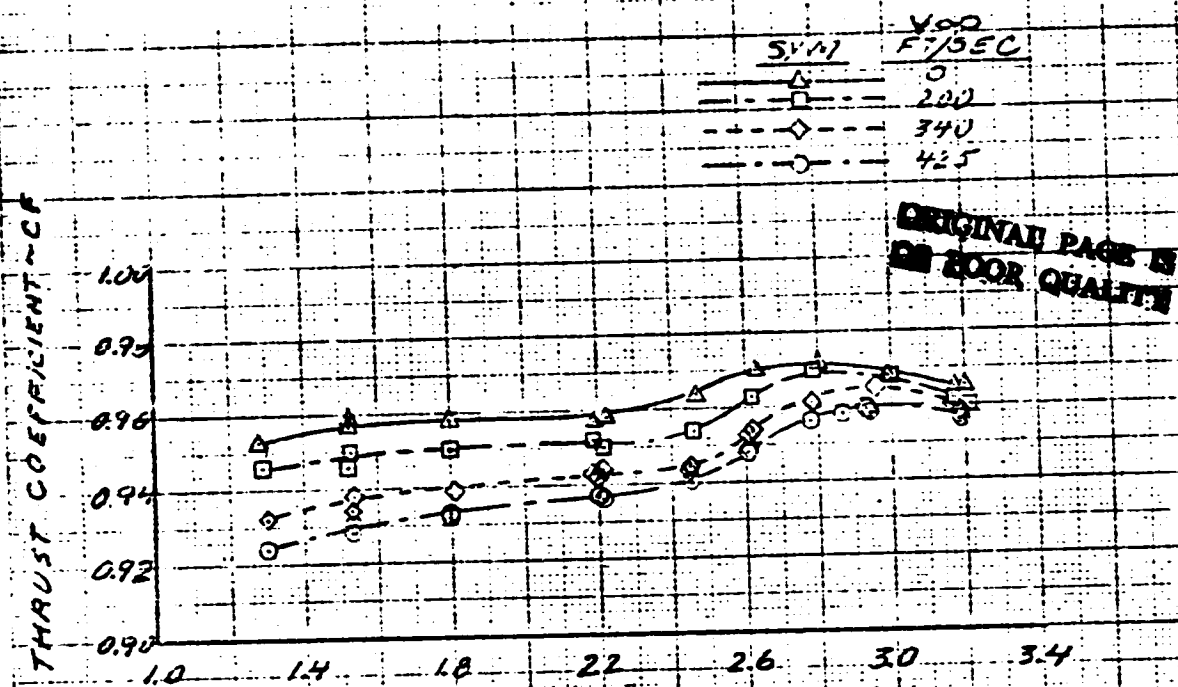
THRUST COEFFICIENT ~ C_F



DISCHARGE COEFFICIENT ~ C_D

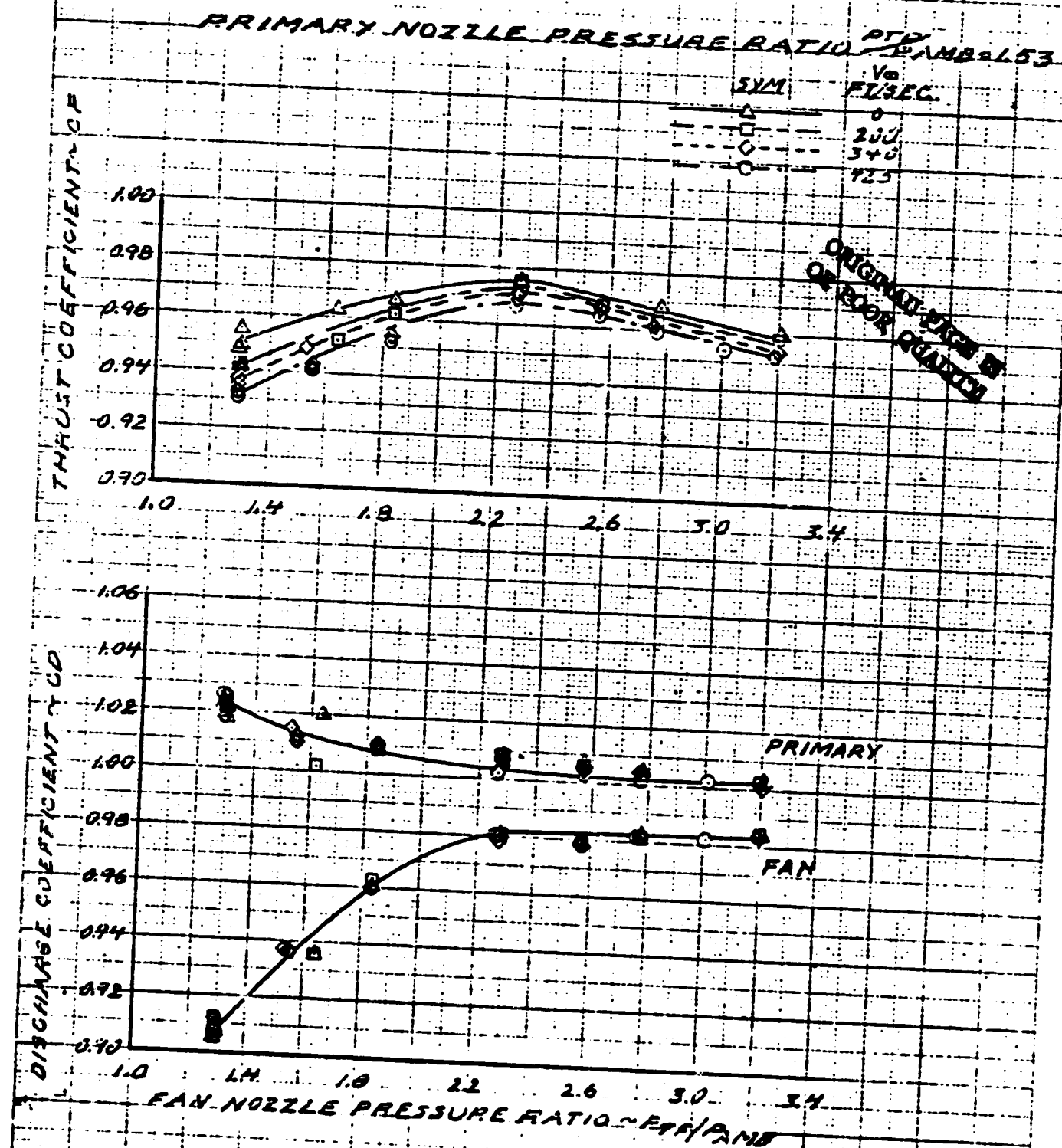


NOZZLE PERFORMANCE **(3) 0.75 AR COANNULAR NOZZLE WITH EJECTOR** PRIMARY NOZZLE PRESSURE RATIO $\frac{P_{T12}}{P_{AMB}} = 1.53$



NOZZLE PERFORMANCE

(4) 1.2 AR COANNULAR NOZZLE



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NOZZLE PERFORMANCE (2) 0.75 AR CONICAL NOZZLE FAN FLOW ONLY

$$P_{TP}/P_{02} = 1.0$$

$V_{02} = \text{STATIC}$

THRUST COEFFICIENT C_F

1.00
.98
.96
.94
.92
.90
.88

1.0 1.4 1.8 2.2 2.6 3.0 3.4

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DISCHARGE COEFFICIENT C_D

1.06
1.04
1.02
1.00
.98
.96
.94
.92
.90

1.0 1.4 1.8 2.2 2.6 3.0 3.4

FAN NOZZLE PRESSURE RATIO $\sim P_{TP}/P_{AMB}$

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NOZZLE PERFORMANCE
(2) 0.75 AR CONVERGULAR NOZZLE
PRIMARY FLOW ONLY

$P_{TF}/P_{AMB} = 1.0$
 $V_{LD} = \text{STATIC}$

THRUST COEFFICIENT $\sim C_F$

1.00
.98
.96
.94
.92
.90

1.0

1.4

1.8

2.2

2.6

3.0

3.4

DISCHARGE COEFFICIENT $\sim C_D$

1.08
1.06
1.04
1.02
1.00
.98
.96
.94
.92
.90

1.0

1.4

1.8

2.2

2.6

3.0

3.4

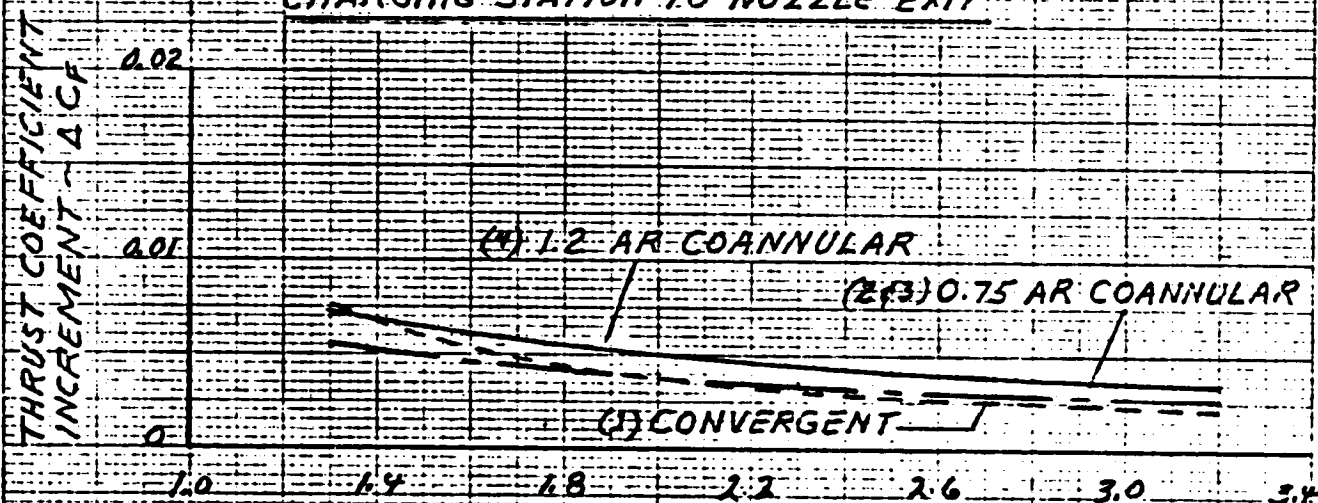
PRIMARY NOZZLE PRESSURE RATIO $\sim P_{TF}/P_{AMB}$

THRUST COEFFICIENT ADJUSTMENTS

FOR COANNULAR NOZZLES -
PRIMARY PRESSURE RATIO $P_{T1}/P_{AMB} = 1.53$

DESIGNED BASED ON
ON BOOK QUALITY

INTERNAL PRESSURE LOSS FROM CHARGING STATION TO NOZZLE EXIT



PRIMARY NOZZLE OVEREXPANSION LOSS

